Cost recovery evaluation of Al Ain construction and demolition waste treatment plant

تقييم استرداد التكاليف لمصنع العين لمعالجة نفايات البناء و الهدم

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Abstract

Waste management is a major challenge facing the developing countries. The rapid urban growth and economic development in Abu Dhabi Emirate has resulted in extreme increase in the daily generation of waste quantity. The Government of Abu Dhabi has initiated several recycling projects toward balancing between the environmental sustainability along with the economic growth to ensure the long-term quality of life of its citizens. The aim of this dissertation is to evaluate the cost recovery of one of the recycling projects in Abu Dhabi Emirate, namely Al Ain crushing and demolition waste treatment plant. In light of the aim the objectives of this research are to explore the cost recovery scenarios for the plant under different policy and economy options, introduce the optimum solution in terms of cost recovery considering the environmental, social, and economic implications, and develop an integrated solution for the management of C&D waste projects in the Abu Dhabi Emirate.

Developing a financial model and considering several assumptions for the relevant factors to determine the cost recovery scenarios of the project, the findings of this research indicate the negligence of clear cost recovery approach and lack of necessary legislations and financial solutions. The identified scenarios elaborated that the current situation will fail in achieving the return on investment during the course of the contract regardless of the adverse environmental and economic impacts of current practices. Moreover, the prevailing practices and activities of the construction industry indicates a real need of major governmental decrees to enhance the supervision and monitoring related activities, create stable market for the recycled materials through government-funded projects managed by public organizations, in addition to intensive awareness and education programs to promote environmentally sound practices. These set of political support, law enforcement, environment considering encouragement, will reform the construction industry toward achieving the waste sector strategy. Nevertheless, the research recommends developing the implementation of tipping fee mechanism as a substantial solution toward the successfulness of the recycling projects in Abu Dhabi.

الملخص

تعتبر إدارة النفايات تحديا أساسيا تواجه الدول النامية. و قد أدى التسارع الهائل في التطوير العمراني و التنمية الاقتصادية في إمارة أبوظبي إلى ارتفاع هائل في كمية النفايات المتولدة يوميا. لقد أنشأت حكومة أبوظبي عدة مشاريع لإعادة التدوير بهدف التوازن بين الاستدامة البيئية و النمو الاقتصادي و لضمان جودة الحياة الاجتماعية لقاطني الإمارة على المدى البعيد. إن الغاية من هذا البحث هي تقييم لعملية استرداد التكاليف لأحد مشاريع إعادة التدوير في إمارة أبوظبي، و هو مشروع العين لمعالجة مخلفات البناء و الهدم.

في ضوء الغاية المذكورة أعلاه، فإن الأهداف المنشودة لهذا البحث هي تحري سيناريوهات و خيارات استرداد تكاليف المشروع في ظل سياسات و أوضاع اقتصادية مختلفة، طرح الحل و الخيار الأمثل من حيث استرداد التكاليف أخذا في الاعتبار التأثيرات البيئية و الاجتماعية و الاقتصادية، و تطوير حل و نظام متكامل لإدارة مخلفات البناء و الهدم في إمارة أبوظبي.

من خلال تطوير نماذج مالية و أخذا بالاعتبار لعدة فرضيات للعوامل ذات العلاقة بسيناريوهات تغطية نفقات المشروع، فإن نتائج هذا البحث تبين انعدام منهج واضح و نقص في التشريعات الضرورية و الحلول المالية اللازمة لعملية استرداد تكاليف المشروع.

لقد وضحت السيناريوهات المحددة فشل الوضع الحالي في تحقيق العائد على الاستثمار للمشروع طوال مدة العقد فضلا عن التأثيرات لسلبية للممارسات الحالية من الناحية البيئية و المالية. علاوة على ما سبق، فإن الأنشطة و الممارسات السائدة في قطاع الإنشاءات تشير إلى الحاجة الملحة إلى قوانين و تشريعات حكومية لتحسين الرقابة و الإشراف على الأنشطة ذات العلاقة، إيجاد سوق متوازنة للمواد المعاد تدويرها من خلال مشاريع مدعومة حكوميا و تدار من قبل مؤسسات عامة، بالإضافة إلى الحاجة لبرامج توعوية و تثقيفية مكثفة لتشجيع أفضل الممارسات البيئية. إن هذه المنظومة من الدعم الحكومي، تطبيق القوانين، و تشجيع الممارسات البيئية، سوف تعيد صياغة قطاع الإنشاءات نحو تحقيق استراتيجية قطاع النفايات. و مع ذلك، فإن البحث يوصي بتطوير آلية تنفيذ رسوم التعرفة كحل جوهري نحو تحقيق النجاح لمشاريع إعادة التدوير في أبوظبي.

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AED: Arab Emirates Dirhams

C&D: Construction and Demolition

CWM: The Center of Waste Management - Abu Dhabi

DMA: Department of Municipal Affairs

DOT: Department of Transport

EAD: Environment Agency - Abu Dhabi

TP: Tipping Fee

QCC: Abu Dhabi Quality and Conformity Council

Chapter 1 – Introduction

1.0 Background:

Solid waste is considered one of most important challenges facing developing cities and urban societies. The rapid industrial change and technological development, associated with increase of population and quantities of generated waste consequently, caused several environmental, social, and economic impacts which negatively affected the water, soil, and public health. Therefore, the waste management occupies center stage in the lists of priorities for the countries for finding scientific and radical solutions problem.

1.1 Context:

Wastes are produced in the normal course of operation in domestic, industrial, commercial, construction, and institutional operations and can be made of organics, non-organics, inert material, hazardous, and recyclable materials. Wastes come in solid, liquid, and gaseous form. Waste is defined as "any discarded, rejected, abandoned, unwanted or surplus matter, whether or not intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the matter (Environment Protection Act 1993).

The quantity of waste generation is related to the population and the economic activities. Arab Countries generate ninety 90 million tons of waste every year. It is predicted to increase to 200 million tons per year in 2020 by which the cost is estimated around five 5 billion US$. The GCC countries are among the top waste generators, whereby the waste generation is 1.2 – 2.7 kg per capita per day (AFED 2011). Abu Dhabi Emirate generates approximately 33,000 tons of waste daily in which 65% is constituted of Construction and Demolition waste.

1.2 Abu Dhabi 2030 vision – Growth Strategy

The 24th objective of Abu Dhabi 2030 vision emphasizes on balance between the environmental sustainability along with the economic growth to ensure the long-term quality of life of its citizens. Therefore, several environmental legislation and incentives were developed to create the sense of environmental respect and consideration in both individual and corporate level.

The Environmental Sustainability Index (ESI) identifies the global ranking based on environmental factors such as natural resources, levels of pollution, and efforts and capacity to protect the environment. Abu Dhabi's 2030 vision gives the protection of environment the utmost importance and ensures that the industrial and economic expansion will not cause negative impacts on the environment. The top-level decision making in Abu Dhabi considers the environmental aspects as important as the social and economic aspects.

1.3 Abu Dhabi Waste Sector Strategy

The strategy document of the Center of Waste Management – Abu Dhabi has identified the lack of treatment facilities, lack of marketing for the recyclable material, lack of communication with public and private sectors, lack of regulatory framework, and ineffective tariff system as high level challenges to create adverse impacts on the waste management sector. (CWMAD strategy, June 2013). On the other hand, the Center of Waste Management – Abu Dhabi strategy has targeted 80% waste diversion from the landfills by 2018 as a high priority five-year objectives, the financial status of the current projects as weakness, and the operational cost reduction through optimizing waste management as an opportunity.

1.4 Problem Statement

(CWM) was constituted by the Government of Abu Dhabi under the decree 17/2008 to manage the waste sector. Based on this decree, the government of Abu Dhabi has allocated certain budget for CWM for its first five 5 years operation. CWM has to provide its services independently and based on the income generated from its own projects.

One of the major challenges faced by CWM is the management of recyclable waste especially the Crushing and Demolition Waste (C&D). The daily generation of C&D in Abu Dhabi Emirate is approximately 65% of the total daily waste generation. Managing the C&D and controlling its environmental, social, and economic aspects is a major problem in Abu Dhabi. Furthermore, according to CWM reports and studies, the daily amount of C&D generation is approximately 21,000 tons, and the cost of managing waste accounts for approximately Dh225 per ton.

In order to manage the C&D waste in Abu Dhabi Emirate, the CWM has outsourced the treatment of C&D waste and established Al Ain Crushing and Demolition Treatment Plant. The environmental and financial objectives of this project has been raised ever since it was introduced and questions are raised regarding its effectiveness. Being an income generator to CWM from the sales of recycled aggregates and recyclable material, the cost recovery in light of the duration of the contract was not discussed.

This project is the largest of its kind in the UAE and serves as a test case for both researchers and practitioners. Being an environmental / commercial recycling initiative, the project is a testing ground for projects of similar nature where the environmental, social, and financial factors stimulate both waste management authorities and businesses to restudy their strategy.

Given the negative enthusiasm from the result of implementation of this recycling project; it becomes necessary to conduct a study of feasibility and the effectiveness of this project given its and to provide recommendations for its improvement. In so doing, to provide a decision making tool for the CWM to learn from the case and where necessary improve the effectiveness of similar projects within the organization. For researchers; to derive results of this case and to apply to similar streams of knowledge and practice in the region.

1.5 Aims, Questions, and Objectives

1.5.1 Aim:

The aim of this research is to explore the cost recovery scenarios in order to improve the financial effectiveness of the C&D treatment plant, taking in consideration the social, economic, and environmental aspects.

1.5.2 Questions:

This paper is meant to answer the following questions:

- Does the C&D waste treatment plant recover the total investment cost during the contract life period?
- What are other available sources of income to enhance the cost recovery of the project?
- Does this project achieve the environmental objectives of a waste recycling facility?
- Considering the waste management as an integrated environmental solution, can the project achieve its goals in isolation of external factors?

1.5.3 Objectives:

In light of this aim, the dissertation has the following objectives.

1. Explore the cost recovery scenarios of the project under different policy and economy options.
2. Introduce the optimum solution in terms of cost recovery considering the environmental, social, and economic implications.
3. Identify related legislations and regulations to assure achieving project's objective.
4. Develop an integrated solution for the management of C&D waste projects in the Abu Dhabi Emirate.
5. Present recommendations based on the study findings and implications for further research.

1.6 Contribution to knowledge

With rapid development in industrial and economic activities, in addition to the high consumption of the natural resources and its environmental, social, and economic implications, waste management becomes one of the most important challenges to face individuals and organizations including both public and private alike. Despite the large number of literature available to practitioners, the current practice of waste management especially in GCC countries has not been considered among the best. Although governments have clearly expressed their political and financial support to environmental activities, the number and variety of the relevant projects, in addition to the environmental outcomes has not been up to the goals and objectives. However, Abu Dubai 2030 vision provides a regional perspective to the existing knowledge of waste management and environment protection.

Considering the financial as well as environmental approach embodied in current projects that have not been comprehensively evaluated, in addition to the future projects that needs a different feasibility perspective, this research and the results of this study can be undertaken to other projects of similar nature.

1.7 Research Content

Chapter one presents an introduction to the research. It provides a brief background and an overview of Abu Dhabi 2030 Plan 2010. In addition, a highlight on the importance of waste management and the problem statement along with the aims, questions and objectives of this research is expressed. Finally research contribution to knowledge is demonstrated.

Chapter two provides the Literature review of this research. The literature review illustrates the knowledge streams of waste management and the principles of relevant activities; waste reduction, recycling, political influences and regulatory actions, in addition to the financial studies with regards to the waste management projects.

Chapter three presents the methodology of this research, as well as the introduction and the process flow of the methodology. Moreover, information collection sources utilized for this research are identified along with the documents/releases/reports reviewed in association with the researcher theoretical perception.

Chapter four covers the analysis and case findings. The chapter presents an introduction to CWM and its initiated project, a comprehensive comparison between the feasibility studies, pre-commencement projections, and the actual results taking into account the environmental, social, and economic implications of considered scenarios.

Chapter five provides the comprehensive discussion considering the relevant factors to determine the optimum scenario of the plant cost recovery.

Chapter six articulates the concluding remarks of this research. A series of recommendations extrapolated from the case findings and analysis are provided along with the suggestions for further research and studies. Finally references used in the research are presented.

2. Literature Review

2.1 Solid Waste Management

Wastes are produced in the normal course of operation in domestic, industrial, commercial, construction, and institutional operations and can be made of organics, non-organics, inert material, hazardous, and recyclable materials. Wastes come in solid, liquid, and gaseous form. This project is directed towards solid waste management, wherein solid waste is defined as "unwanted or useless solid material generated from combined residential, industrial and commercial activities in a given area". Waste management strategies are intended to reduce or eliminate the effects of waste on the environment, to provide for public and worker safety, and to maximize the efficient use of resources. Proper solid waste management reduces or eliminates the adverse impacts on human health and the environment and supports the development of growing economies and helps improve the value of life.

The management of solid waste involves several process operations form monitoring, collection, transport, processing i.e. treatment or recycling, and disposal. These processes are subject to laws, rules, and regulations. The United Arab Emirates (UAE) adopts waste management practices that are based on international standards. The local and federal directives present the roles and responsibilities of all concerned parties. The rules and regulations governing the generators and transporters of waste, in addition to those governing the collection and transport, and treatment, storage, and disposal (TSD) facilities are provided in the specified laws governing the generation and management of wastes (for example Local Law No. (21) of 2005 for Waste Management in the Emirate of Abu Dhabi).

Waste management is based on the "3R principle" i.e. reduce, reuse, and recycle. The most effective and proactive management practice is to eliminate or reduce the generation of the waste. This is referred to as pollution prevention. Minimizing or avoiding the creation of pollutants and waste can be more effective in protecting the environment than treating them, or cleaning them up after they have been created. Pollution prevention methods are designed to eliminate the creation of waste in contrast to pollution control options that treat waste after it has been created. Waste generators can reduce costs and prevent pollution by implementing reduction, reuse and recycling programs through changes in operational procedures, maintenance practices, and raw material usage.

Sustainable waste management necessitates the requirement for waste avoidance and waste minimization at source and these options are the first to be considered in the hierarchy of waste management. Source reduction is the practice of reducing the amount of raw material entering a waste stream or being released into the environment before recycle, treatment or disposal. The aim of reduction is to eliminate the production of a waste by using raw materials more efficiently and effectively. Methods of reduction include substitution or reduction of a raw material, production redesign, process changes, and improved maintenance activities. Second in the hierarchy of waste management is reuse and recycle of useful resources from wastes. Reusing or recycling hazardous waste in operating processes and the reuse of material that would otherwise require treatment or disposal within the generating facility are other means of pollution prevention. The recycling of materials within an industry can significantly reduce the quantities of waste generated. Furthermore, waste exchanges and waste associations offer some opportunity for the reuse or recycle of waste in addition to placing potential users of waste materials in contact with waste generators.

Once waste has been created the proper treatment and disposal can be expensive and treatment options should be considered only after acceptable waste minimization techniques have been identified. Various waste management options are available to reduce the cost and volume of waste requiring treatment. The process for identifying options should follow the hierarchy in which reduction options are explored first and reuse and recycling options second. The hierarchy effort stems from the environmental desirability of source reduction as the preferred means of minimizing waste with main emphasis on the diverting of waste from disposal at landfills and dumpsites to more sustainable management techniques in order to maximize resource recovering and utilization of renewable biomass.

Waste treatment techniques transform the waste into more manageable form reducing the volume and toxicity therefore making the waste easier to dispose of. Treatment methods are dependent upon composition, quantity, and form of the waste material. Some waste treatment methods being used today include subjecting the waste to extremely high temperatures i.e incineration or gasification, dumping or landfilling, and using of biological, chemical, or physical processes for waste treatment. It should be noted that treatment and disposal options are chosen as last resort, that being in reference to the 'best practice' waste management strategies promoting reducing, reusing and recycling of waste. In general, more than one process is used for treatment, with some physical and chemical processes often applied first followed with other final solution processes. No single process is suitable for all categories of solid waste and frequently several processes are linked in series or in parallel configurations to form waste-specific treatment methodologies. Therefore, all of the available treatment and disposal options must be evaluated, in lieu of possible recycling options, and the best combination of the available options matched.

Wastes are important because of their potential hazard to human health and the environment for when they are improperly transported and stored, treated, recycled, and disposed of. Reports indicate that, for industrial developing nations, the increase in Gross Domestic Product (GDP) is an indicator of the increase in the generation of waste. Based on the examination of waste generation trends in the United States, the Environmental Protection Agency (EPA) the estimated waste generation rate per person per day is 4.6 pounds (for total waste not just MSW waste) for the generation quantity of 240.9 million tons (OECD, 1999). The Organization for Economic Co-Operation and Development (OECD) in 1999 examined the global MSW generation rate trends in OECD countries and showed that the waste volume is expected to continue growth in quantities (from 1995 to 2020) and that the trend is not related to population numbers. The estimated waste quantities in 1997 for European countries where indicative of the worldwide waste generation trends and show that the volume per capita ranges from 170 kg per person per year in Finland for example to 530 kg per person per year in Denmark. The data was collected for MSW waste and not total waste (OECD, 1999).

MacFarlane (1998) studied the linkage between waste generation rates and consumption of resources based on the expansion in sustainable development and the involvement of the public sector and private sector in the reduction, reuse, and recycling of waste materials. The relation between per capita solid waste management costs and per capita Gross National Product (GNP) showed that cities in general for both industrialized and developing countries do not spend more than 0.5% of their capita GNP on municipal waste management services. Of this total budget, an approximate of 45% is spent on intermediate treatment facilities (i.e. incineration plants) with around 4% allocation towards collection projects and 6% for final disposal projects. This was for high income countries. For low and middle income countries it was advised that the major portion of the solid waste management budget is allocated to collection and transportation services. Final disposal costs were seen to be minimal because in these countries disposal was most of times done through open dumping rather than through containment in proper designed landfills.

Similar trends were observed for when comparing landfill tipping fees. In the United States, for example, the weighted average tipping fee is $94/ton being based on conservative assumptions of the waste mix. This is not to include high tipping fees waste materials (e.g. hazardous wastes) such as oil waste material that have tipping fees of almost $250/ton and industrial paint tipping fees that reach almost $400/ton for disposal. It is worth noting here that tipping fees in the European Union are on average higher than those in the United States, this being the reflection of economics of landfills in developed areas of dense population. There was significant difference observed between the tipping fees charged in developing countries and those tipping fees charged in the European Union countries and in the United States. For example, tipping fees charged were as low as $ 1.3/ton in Indonesia.

2.2 Construction and Demolition Waste

There is no uniform definition of Construction and Demolition waste "C&D waste''. C&D waste in general refers to the solid waste generated in the construction sector. More specifically, C&D waste is "waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation" (Shen et al., 2004). In the United States, C&D waste has been defined as solid waste that is produced in the process of construction, renovation, and demolition of structures, roads, and bridges being that which is composed of concrete, asphalt, wood, metals, gypsum wallboard, and roofing material Franklin et al. (1998). Moreover, in similar but more comprehensive understanding, Shen et al. (2004) and Tam and Tam (2008) defined C&D waste as "waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation".

C&D wastes include a wide range of materials based on the source of the C&D waste (Fatta et al., 2003). These include (i) excavation materials (e.g. earth, sand, gravel, rocks and clay) (ii) road building and maintenance materials (e.g. asphalt, sand, gravel and metals) (iii) demolition materials (e.g. debris including earth, gravel, sand, blocks of concrete, bricks, gypsum, porcelain and lime-cast) and (iv) other worksite waste materials (e.g. wood, plastic, paper, glass, metal and pigments) (Fatta et al., 2003). In the UAE, Globex-City Consultant in 2002 reported that significant variation in the composition of C&D wastes reaching the Al Dhafra landfill were observed, with aggregate materials (i.e. rock, concrete, brick, stone, and soil) forming the major portion of the C&D waste stream. It was concluded that variations of the source of waste, variation of the segregation competence or mixing of C&D waste with other waste streams resulted in the composition differences which in turn impacted the landfill operations and increased costs.

During construction, few material of high economic value are separated for recycling purposes (e.g. plastic films and scrapping materials). Demolition of buildings is in general carried out in two phases. First, interior finishing are removed from the buildings and these can (1) be sold directly for reuse, or (2) be taken to locations of demolition sites for later sale, reuse, or recycling, or (3) be transported to dumpsites should there be no other favourable possible solutions. Second, concrete structures are then themselves demolished and the steel contained in the demolition debris is removed to the most extent possible for sale to scrap dealers whiles the concrete blocks are used for landscaping projects or sent to dumpsites. Asphalt removed from road refurbishment is in most times mixed into new asphalt or used for new sub-bases.

ICF Incorporated in the report to the Environmental Protection Agency (EPA) that was published in 1995 identified the following main factors impacting the characteristics of C&D waste (i) type of structure (e.g. residential or non-residential i.e institutional; , commercial, or industrial such as building, road, and bridge configuration) (ii) size of structure (e.g. low-rise, high-rise). And (ii) work being performed (e.g. construction, renovation, repair, demolition).

Several factors influence the production of C&D waste (Dolan et al., 1999). These are explained as the following:

- Extent of economic growth and overall development. This in effect is responsible for sector expansion and work progression in construction, renovation, and demolition.
- Special grand scale projects, such as urban rejuvenation, road construction and mega structure repairs, and others such as unplanned happenings resulting from 'force majeure' or natural related disasters.
- Presence of supporting infrastructure i.e. storage locations, pre-sorting areas and deposit sites or landfills and recycle processing facilities etc., and costing of collection and transport, and treatment or recycle, and disposal solutions.
- Laws, rules, and regulations concerning segregation at source, reduce, reuse, and recycling of C&D waste. Comprehensive guidelines that can have practical application which is to be in compliance with international standards.
- Extent of end-use markets and governmental support and qualitative standardization of recyclable materials for obligation purchasing of contractors having projects with government organizations.

Waste generation determination can take place through direct or indirect methods. Direct methods for determination of waste generation and composition include weighing, measuring, and segregating or sorting of the waste stream or these can include sampling and extrapolation (Brunner and Ernst, 1986). Indirect methods (Hsiao et al., 2002) estimate the waste generation rate using statistics on consumption, trading, and other economic indicators (e.g. stockpile storage).

C&D waste management operations range from reusing to recycling to disposal in landfills (Peng et al., 1997). The most common solution for C&D waste is landfilling either in specified permitted C&D waste landfills or municipal solid waste (MSW) landfills, as well as in non-permitted locations such as illegal dumping sites. Most of the C&D waste stream is composed of inert solid waste and therefore regulations do not require that C&D waste landfills provide for the same level of environmental protection (layers and liners, leachate collection systems, etc.) as MSW permitted landfills. Therefore, C&D waste landfills generally have lower tipping fees, and handle a large fraction of the C&D waste that would otherwise be sent for further processing.

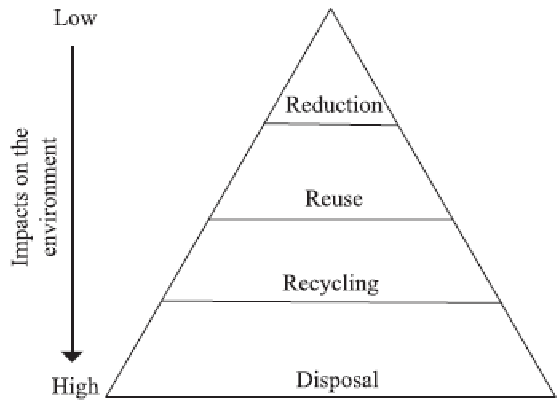

Figure 1: The C&D waste management method hierarchy (Yuan and Shen, 2011)

Examining the effectiveness of the theoretical C&D waste management strategies, Shen et al., 2006) demonstrates the reasons by which these C&D management principles fail in practice which majorly refer to the lack of economic incentives. Therefore, it is of great importance to review the cost-benefit analysis endeavors to investigate the effectiveness of the C&D management practices.

Several studies have been conducted based on different instruments for examining the financial effectiveness of C&D management, such as investigating related economic factors such as disposal cost, resources, and collection (Mills et al. 1999), using mathematical equations to identify the feasibility of waste minimization (Begum et al. 2006), and performing model based study to assess the feasibility of C&D marketing by considering source tax and subsidies (Duran et al. 2006). The C&D waste management is of a complicated and dynamic nature in which several factors interact and determine the viability of this practice. Using a system dynamic approach and focusing on C&D management activities throughout the waste chain, the cost-benefit analysis of (Yuan et al. 2011) illustrates the landfill fee as a substantial factor to determine the benefit of C&D management activities. However, high landfill charge will lead to illegal dumping and subsequently to higher environmental management loss. Thus, the study strongly recommends to facilitate the landfill fees through promoting necessary regulations. In addition, it highlights the basic factors to affect the C&D management, namely (1) Environmental awareness as a qualitative variable that influences the willingness of various parties to manage C&D waste. The awareness of reducing C&D waste can be raised through regulation strengthening. (2) Waste collecting as a vital and positive activity in terms of promoting waste sorting, and reducing the illegal dumping. (3) Illegal disposal which could be overcome by regulations and penalizing the non-compliant party. (4) Waste sorting as a factor to promote waste recycling. (5) Recycling and reuse as a fundamental activity to increase waste minimization and subsequently the benefit of waste management. (6) Regulations as a strong political impact to control waste management activities. Tighter regulations lead to lower amount of illegal dumping, while loose regulations lead to higher amount of illegal dumping. (7) Total cost of waste management which includes both the income generated from the sale of recycling, and the cost of treating the effect of pollution and the illegal dumping.

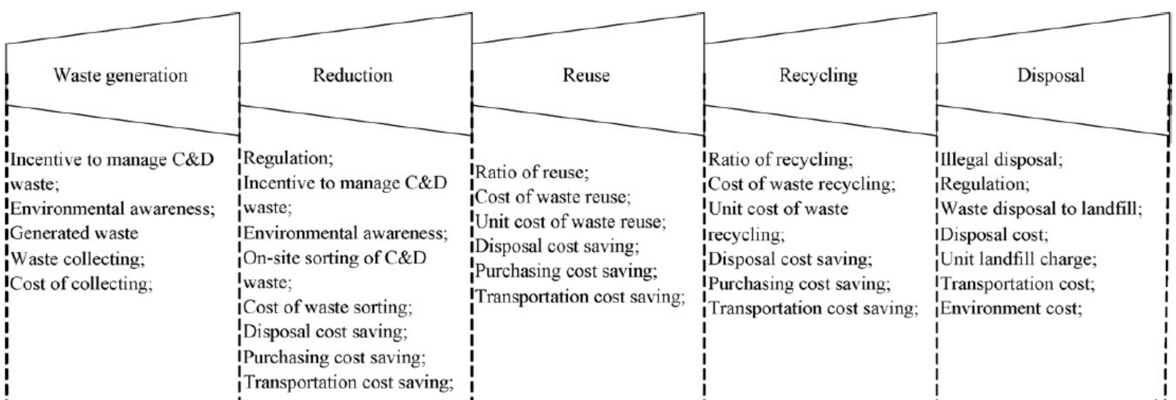

Figure 2: A conceptual model of the C&D waste chain (Yuan et al. 2011)

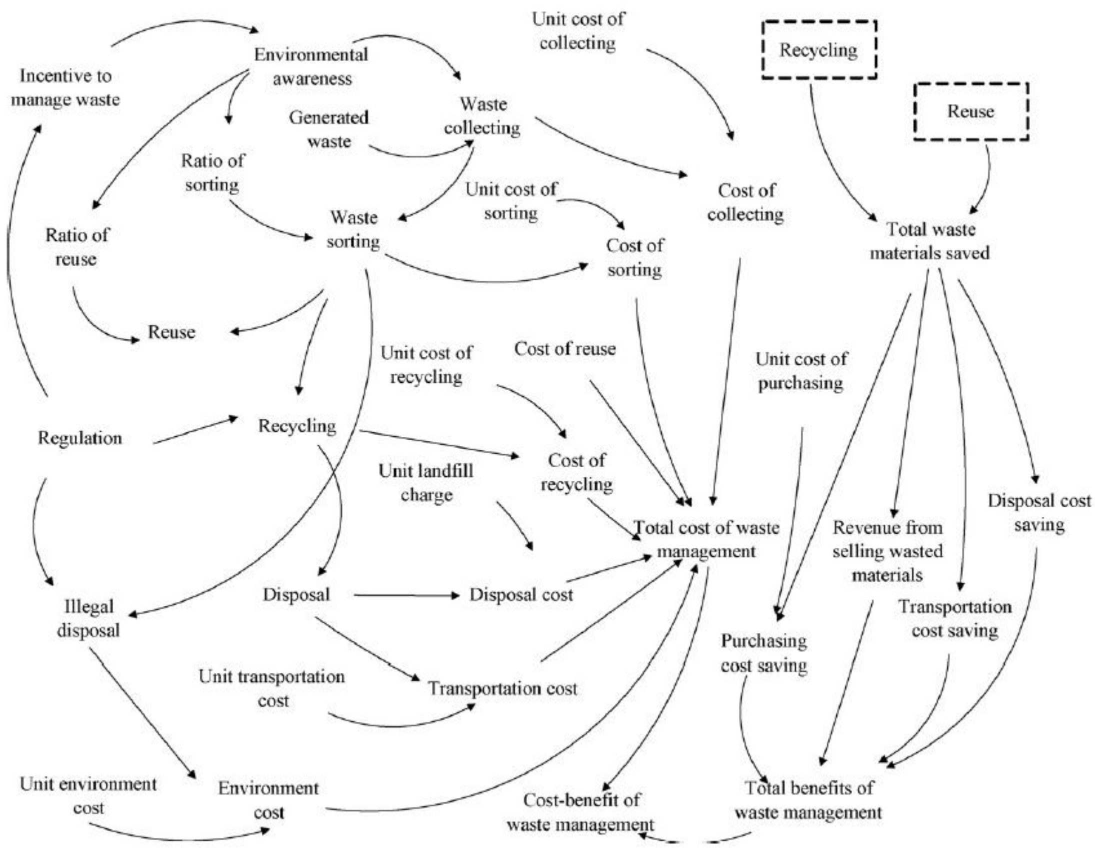

Figure 3: Casual loop diagram of cost-benefit analysis of the C&D waste management (Yuan et al. 2011)

Recycling C&D waste reduces the dependence on natural resources and creates less pollution through lowering manufacturing and transportation related emissions. Reduction of the energy and water required to produce building supplies from raw materials also contributes to the reduction of greenhouse gases related to the manufacturing and transportation of those materials. Concrete, asphalt, metals, and wood are most frequent to be recovered and recycled, on the other hand, gypsum wallboard and asphalt grits are least frequent to be processed for recovering and recycling. The major obstacles to increase in the recovering rates for these materials are the following:

- Relative costing of collecting, sorting, and processing as compared to virgin high quality product materials.

- Low value of the recycled-content material in relation to the cost of virgin based materials, which impacts the marketable value of these recycled products.
- Reduced costing of C&D waste landfill disposal in comparison to more expensive process plant recycle or treatment options.

C&D waste is generated worldwide. Sandler and Swingle (2006) showed that an approximate of 136 million tons of building related C&D waste is generated each year in the US, out of which only 20–30% is recycled. In the UK, it was reported that every year around 70 million tons of C&D materials and soil ended up as waste (DETR Circular, 2000). In Australia, C&D waste generation accounted for 16–40% of the total solid waste generated (Bell, 1998) whereas In Hong Kong almost 2900 tons of C&D waste was received at landfills per day in 2007 (Hong Kong EPD, 2007). China is responsible for the production of 29% of the municipal solid waste of the world each year, of which construction activities contribute for nearly 40% (Dong et al., 2001; Wang et al., 2008).

The generation quantities of C&D waste are consistent with those presented prior for MSW. For example, in the European Union, more than 450 million tons of construction and demolition waste are generated on annual basis (EC, 2000). The stream presents the third largest in quantity following from the quantities of waste from the mining and farming industries (Dorsthorst and Kowalczyk, 2002). Moreover, in 2006, Spain generated roughly 47 million tons of C&D waste, of which only 13.6% was recycled (Eurostat, 2011). This resulted in the drafting of laws, rules, and regulations on C&D waste forcing EU countries to include new measures for waste prevention and waste recycling. Among which, the mandating that estimated C&D waste expected to be originated during construction projects be quantified. This ratio indicated that the planning and execution of construction works did not take into consideration the environmental factors because of the low cost of dumping and the easy readiness of natural resources.

In addition the European Environment Agency (EEA) estimated that on average 65% of the waste generated was recycled in 2006 in the 27 European countries. The information indicated that Spain showed much lower recycling rates than the rest of the EU countries on average and was far from other EU countries such as Denmark, Estonia and the Netherlands, which showed recycling indexes of over 90% (Tojo and Fischer, 2011). Nonetheless, the data are far from achieving the targets set by the EU for 2020 wherein 70% in weight increase is to be achieved in the treatment, recycling and other operations of C&D waste, excluding those in the 17 05 04 category of the European Waste Catalogue (EWC) (Ministry of the Environment, 2002). Because of this, the EU countries are implementing national policies as well as different measures for increasing the recycling and recovering of C&D wastes. To that effect, the Spanish government issued the 105/2008 Royal Decree (RD) (Ministry of the Presidency, 2008). This RD regulated the production and management of C&D waste and focused on the establishment of the legal frame work for C&D waste production so as to encourage prevention, reduce, reuse and recycling, as well as other forms of valorization.

Nassour et al (2008) examined the status and perspectives of waste management in the Arab countries. For almost all the Arab countries (which are developing countries) waste management conceptions were determined to be still in the premature stage. Most generated waste in Arab countries seemed to be deposited in simple landfills and there were close to zero waste recycling plants in the Arab world though some sorting stations existed for the separation of waste recyclable fractions. Nonetheless, the study showed that work on plans for the establishment, construction, and operation of waste treatment plants for the production of high calorific-value fractions (such as RDF) to be used as secondary fuel in cement industries has started. The report indicated that the amount of MSW generated per capita ranged between 0.3 to 5.0 kg depending on the region being considered with the organic waste fraction having the maximum composition percentile (70%) whilst the wood waste portion was seen to have the minimum composition amount. Moreover, it was determined that the lack of clear legal guidelines, specifications, norms and functioning organizations, as well as environmental policies and legal frameworks, in addition to lack of community involvement etc. where the main drawbacks of the Arab countries in the waste management field leading to non-compliance with existing laws, rules, and regulations and lack of proper control, monitoring, and inspection of the waste management practices in the Arab countries. The report concluded that the lack of proper knowledge and poor allocation of funds were the root of the problem which was still considered to be "the suitable treatment of waste and the optimization of disposal logistics" citing that most Arab countries at present had systems in place for collection, transport, and disposal not treatment. The above applied to C&D waste in as much as MSW.

On a local scale, the CWMAD, in reference to the quantification of the generation of municipal solid waste in the Emirate of Abu Dhabi in the UAE, compiled the waste generation data available from the waste management contracts into an internal report providing baseline data of the waste stream quantities. The internal report was completed in the year 2011. The report examined the quantity of waste generation in Abu Dhabi, Al Ain and Western region was determined on the basis of the reports from the weighbridge tickets and from the approximate estimation where no weighbridge data was available. The data showed that the total quantities of all kinds of wastes generated Emirate of Abu Dhabi approximated 33, 247 tons/day where almost 50% of the total waste comprised the C&D waste portion that generated from the construction activities in the region of Abu Dhabi. The report concluded that because of the non-availability of weighbridges at the dumpsites in Al Ain and the Western region, the quantities of waste received at the dumpsites are not recorded nor classified moreover, it was recommended that comprehensive waste audit studies be conducted to determine the proper quantities and correct compositions of all wastes generated in the Emirate of Abu Dhabi. It is worth noting here that before 2011 there were no C&D waste recycling plants in the emirate of Abu Dhabi. For comparison purposes, the report referenced prior data estimations for the C&D waste quantities in Al Ain (from Entec in 1998) which had showed that the generation rates were between 750,000 tons/year and 1,000,000 tons/year in the Al Ain region. The data was compared to that which was approximated based on the one week inspection of incoming C&D waste at the Al Dhafra dumpsite in Abu Dhabi (from Globex-City Consultant, 2002) which showed that the amounts of C&D waste received approximated 1,000 tons/day. Moreover, it was stated that indirect estimates from Fichtner in 2005 showed similar results of comparable numbers (i.e. 920 tons/day to 940 tons/day).

2.3 Environmental Considerations

There is an important need to manage C&D waste in proper manner in order to reduce its negative impacts on the environment. C&D waste has attracted widespread concerns from global economies as it has become quite problematic from the environmental stance (Mills et al., 1999; Begum et al., 2006; Hao et al., 2007; Wang and Yuan, 2009). Harmful impacts of C&D waste on the surroundings exist and utilizing large amounts of land reserve for C&D waste landfill disposal is of major importance. In the United States, restricted landfill capacities together with the complications involved in the developing of new landfill spacing has led to difficulties in the absorbing of excess amounts of C&D waste for land disposal which is becoming of major concern to regulators (Wang et al., 2004).

Common practice in most parts of the world has been to discard C&D waste in landfills most often the same ones being utilized for the disposal of MSW (Garrido et al., 2005). This has led to considerable environmental concerns because of the substantial generation in volumes of C&D waste which presented significant pressure on the capacities of landfills. (Esin and Cosgun, 2007). In all cases, however, the disposal of C&D waste cannot be seen to as the most proper sound management practice for such end of life building materials. Fatta et al. (2003) showed that several cases have been reported where C&D waste ended up in uncontrolled open dumpsites causing severe burden on the environment, this being apart from the aesthetic degradation. The environmental impacts of these wrongful practices, from soil and water contamination to air pollution in addition to the possible resulting fires, leads to the destruction of these open spaces and affects the landscape and reduces land value (El-Haggar Salah, 2007). C&D waste might also include asbestos waste in addition to other hazardous waste which might pose significant health risks in specific in building sites that are later converted into residential areas or children playgrounds (Hendricks et al., 2000). Overall, it can be harming to the surroundings causing hazardous pollution and can waste natural resources.

Possible sound practices for C&D waste reduction include the following:

- Waste prevention which can be promoted through record control and return allowances for construction material in possible attempt to promote possible reuse of the waste materials.
- Selective demolition which involves dismantling selected parts of buildings to be demolished before destruction in order to recover the materials.
- On-site separation systems, for segregation at source using smaller equipment and removing useful material for recycling.
- Crushing, milling, and reuse of secondary stone and concrete materials in order to achieve specifications similar to approved road construction materials specifications.

Natural aggregates comprised of sand, gravel, crushed stone, and quarried rock are used for the preparation of the foundation material for construction purposes (Poon et al., 2006). Prevailing standards for fine aggregates and coarse aggregates provide for the specifications of the standard sizes of aggregates in compliance with grading requirements. Tam and Tam (2006) advised that the applications for recycled aggregates, based on their specifications, sourced from the C&D waste recycling facility, include (i) use as foundation material for road construction works; (ii) use as hardcore for foundation applications; (iii) use as base or fill for drainage related functions; and (iv) use as aggregates for concrete manufacturing and general bulk filling purposes. Recycled concrete aggregates are different from natural concrete aggregates. This is because impurities like cement stones are still attached to the surface of the original natural concrete aggregates even recycling. It is the high porosity of the cement stones and the other impurities that contribute to the lowering of the particle density and overall higher porosity of the recycled concrete aggregates resulting in qualitative differences in the recycled concrete aggregates the and the increased water absorption properties (Paranavithana and Abbas, 2006). The specifications of the recycled concrete aggregates in turn shall impact the marketing value of these products as it must be consistent with the prevailing standards for the natural aggregates so that it granted government approvals.

2.4 Illegal Dumping

Illegal dumping is any unauthorized disposal of waste on any public or private property. Usually, people dump illegally to avoid collection and disposal fees, or because they believe proper disposal is just "too much trouble”.

Illegal dumping of waste specially the hazardous waste can cause contamination of the ground water, harm the local environment through damaging vegetation and leaching of hazardous material into soil, threaten air quality in case of fires, and cause direct effects on peoples’ health. In addition, removing the illegal waste and treating the pollution increase the economic burden on the governments.

Chapter 3- Methodology

3.0 Introduction

From the review of literature there are several key factors which contribute to the economic feasibility of C&D waste management projects, namely: (a) profit; (b) unit recycling cost; (c) project specific factor such as extra revenue from location advantage.

On the other hand, not only the ratio of savings to costs varies between public and private sector based on these factors, but also the design of recycling centers and selection of governmental instruments are dependent on these factors as well.

Although it is evident that the fluctuation of the relevant factors will determine the economic viability of any given project, however, the literature illustrate that the above mentioned factors are identified from a static point of view.

Therefore, considering the high dynamic nature of C&D waste chain activities and the integration of its essential elements, will provide a better insight to determine the relevant key factors and understand the Interactions among the involved elements.

More specifically, other relevant factors are identified to determine the result of cost-benefit analysis of C&D waste projects, such as: (1) Environmental awareness; (2) Waste collecting; (3) Illegal disposal; (4) Waste sorting; (5) Recycling and reuse; (6) Regulation.

In light of the literature reviewed and the stated aim of this research; a model-based case study approach is utilized.

Since the case study approach is implemented to maximize the knowledge gained, in addition to the notion that it enables researchers to determine the reasons of decision making and the method of implementing those decisions, the case study approach is considered appropriate for this research (Stake, 1995; Yin, 2003).

3.1 Data Collection

The data collected for this study are secondary. The data collection comprised three activities to enable the understanding of the problem statement and to support the findings.

1. The data about generation and composition of C&D waste in Al Ain prior to the plant construction, were collected from the report and study provided by Municipality's consultant; (Entec Euorope)

2. The data about the actual generation and composition of C&D waste in Al Ain were collected from Service Provider reports; (Star International).

3. Other data concerning the related key factors such as waste management strategy and illegal dumping, were collected from reports provided by CWM / Competent Authorities.

3.2 Model construction and description

The Crushing Plant financial model is a Basic and simple Accounting Model which has been developed in Excel Worksheet. The purpose of developing the Model is to determine the optimum parameters and conditions to recover the Cost of Investment made by the Government.

The Model is divided into four (4) sub-modules which are described as follows:

3.2.1 Module-1 (Basic Assumptions)

Figure 4 presents the basic assumptions module which consists of the main parameters by which the total percentage of both recyclables and aggregates and subsequently the revenue generated are determined. These main parameters are as following:

a) **Crushing Plant Capacity:** The Crushing Plant has been designed to process a maximum of 2000 tons/day of Construction & Demolition waste delivered at the facility. This is a theoretical design capacity on sixteen (16) hours of daily operation on a six (6) days working week. The actual capacity based on time loss due to operational problems and maintenance is less than the design capacity.

b) **Quantity of C&D Waste received at the facility:** This is the actual quantity of waste delivered to the Crushing Plant facility. The quantity has not been very inconsistent due to lack of regulation and control by the Municipality for the disposal of C&D Waste.

c) **No of Working Days:** The Plant operates on a six (6) days/week at the rate of sixteen (16) hours per day. The total no. of working days excluding the Friday works out to be 313 days per year. This value has been considered as fixed during the modeling of the scenarios.

d) **Tipping Fees:** This is a fee which is applied for the acceptance of C&D waste at the Crushing Plant Facilities in many countries of the world. However, this fee has not been applied nor practiced in the Middle East Countries. The only fee which the Center of Waste Management collects from the C&D waste transportation companies is the NADAFA Tariff fee, which is AED 10/= per trucks irrespective of the size and quantity of C&D Waste. This parameter has been widely used in several scenarios in order to improve the Return of Investment (ROI) rate during the contract period and life time of the Crushing Plant equipment.

I. BASIC ASSUMPTIONS

Crushing Plant Capacity	*2,000*	*Tons/Day*
No. of Workings Days / Year	*313*	*Days*
Tipping Fee	*-*	*Dhs/Ton*
Selling Price - Option 1	*12.00*	*Dhs/Ton*
Selling Price - Option 2	*14.00*	*Dhs/Ton*
Selling Price - Option 3	*16.00*	*Dhs/Ton*

Figure 4: Basic assumption of the financial model

3.2.2 Module-2a (Revenue generated from Recyclables)

Figure 5 presents the module-2a of the financial model including the parameters which determine the total revenue generated from the recyclables. The recyclables are categorized by type and the percentage of each type is fixed. However, the daily sales of each recyclable are determined based on the daily received quantity of C&D waste. This module consists of the following parameters:

a) **Recyclables recovered from C&D Waste:** The Feasibility report of the Crushing Plant has assumed that the recyclables like Ferrous (iron), Plastics (bottles, jars, and utensils), Plastic Films, Wood, Paper and Cardboard will be available in the C&D waste stream. However, the Crushing Plant has only been receiving Steel which are embedded in the Concrete and which cannot be recovered manually. The other recyclable materials are not received at the facility and probably recovered and recycled from the source. Further, the Estidama (sustainability) initiative of the government requires the construction companies to recover the recyclables at the source and deliver the C&D waste to the facility in segregated form.

b) **Selling Price of recyclables (unit price):** This is another important parameter which is not fixed and fluctuates according to the market demand. Average market price for the steel (iron) has been used to calculate the revenue from the recyclables. Due to absence of other recyclables in the waste stream, only steel has been used for the modeling of the scenarios. Other recyclables, as and when available in the waste stream can be priced in the module.

	Material Type	Sales (%)	Daily Sales (Tons/Day)	Annual Sales (Tons/Year)	Unit Price (Dhs/Ton)	Sales (Dhs/Year)
RECYCLABLES						
R-1	Ferrous	0.445%	8.90	2785.70	600.00	1,671,420.00
R-2	Plastic	0.060%	1.20	375.60	300.00	112,680.00
R-3	Plastic Film	0.011%	0.22	68.86	200.00	13,772.00
R-4	Wood	1.356%	27.12	8488.56	0.00	-
R-5	Paper Cardboard	0.334%	6.68	2090.84	290.00	606,343.60
TOTAL SALES OF RECYCLABLES		2.21%	44.12	13809.56		2,404,215.60

Figure 5: Module-2a (Revenue generated from recyclables)

3.2.3 Module-2b (Revenue generated from Aggregates produced)

Figure 6 presents the module-2b of the financial model including the parameters which determine the total revenue generated from the aggregates. The aggregates are categorized by size and the percentage of different aggregates is fixed. However, the daily sales of each aggregate are determined based on the daily received quantity of C&D waste. This module consists of the following parameters:

a) **Types of Aggregates:** The Al-Ain Crushing Plant produces four (4) different sizes of Aggregates from the processing of C&D waste at the Crushing Plant. The size of the Aggregates are 0-20mm, 0-30mm, 20-50 mm and >50 mm. The aggregates of sizes 0-20mm and 0-30mm does not have a very high demand in the market. However, the sizes 20-50mm and above are recommended to be used as sub-base and road base materials by the Municipality and is thus on Sale.

b) **Unit price of Aggregates:** This parameter has been assumed in order to calculate the processing cost of Aggregates. This value can be modified or amended depending on the selling price of virgin aggregate materials available in the market.

AGGREGATES						
A-1	Fraction 0-30 mm Trommel	21.00%	420.00	131,460.00	0	-
A-2	Fraction 0-20 mm Screen	19.88%	397.60	124,448.80	0	-
A-3	Fraction 20-50 mm Screen	22.72%	454.40	142,227.20	19.00	2,702,316.80
A-4	Fraction >50 mm Screen	14.19%	283.80	88,829.40	17.50	1,554,514.50
TOTAL SALES OF AGGREGATES		**77.79%**	**1,555.80**	**486,965.40**		**4,256,831.30**

Figure 6: Module-2b (Revenue generated from Aggregates produced

3.2.4 Module-3 (Cost of Processing Aggregates)

Figure 7 presents the module-3 of the financial model including fixed items as the breakdown of the total cost of the plant. This module consists of the following items highlighting the total cost in a monthly, annual, and full duration of the project:

a) **Cost of Crushing Plant Construction:** This parameter consists of the total cost of constructing the Crushing Plant facility, mainly the civil work. The price is fixed as AED 26,022,900.

b) **Cost of Plant, Vehicles and Equipment:** The total cost of Mechanical, Electrical and Plumbing is taken into consideration by this parameter. The cost is fixed as AED 32,552,992.

c) **Operation and Maintenance Cost**: This is the cost of running the operation of the Plant for a period of twenty years (20). The cost is fixed as AED 114,653,950.

This module also estimates the revenue generated by selling the aggregates, recyclables and tipping fee, if it has been taken into consideration. Further, cost of processing per ton of C&D waste and the Break even selling price of the aggregates is also estimated.

III. COST OF PROCESSING C&D WASTE					
		20 Years (Dhs/20 years)	**Annually (Dhs/Year)**	**Monthly (Dhs/Month)**	
COST OF CRUSHING PLANT					
	Crushing Plant Construction	26,022,990.80	1,301,149.54	108,429.13	
	Plant, Vehicles and Equipment	32,552,992.81	1,627,649.64	135,637.47	
	Operation and Maintenance (O&M)	114,653,950.72	5,732,697.54	477,724.79	
TOTAL COST OF CRUSHING PLANT		**173,229,934.33**	**8,661,496.72**	**721,791.39**	

Figure 7: Module-3 (Cost of Processing Aggregates)

3.2.5 Module-4 (Return of Investment)

This is the final module consisting of the break-even price, which is used as a baseline data for adjusting the price of selling the aggregates in order to recover the total cost of investment. The selling price can be adjusted to be make it affordable for the market as well as recover the total investment made by the government.

In case, the selling price cannot be reduced, then the tipping fee may be required to be imposed and adjusted accordingly to match the recovery of total investment. The model can be re-run by changing the value of parameters and assumptions, thus producing a scenario which is considered as the preferred scenario under ideal terms and conditions.

Chapter 4 Case findings and analysis

4.0 Introduction

The economy of the United Arab Emirates (UAE) is primarily being fuelled by the oil sector, as it represents more than one-third of its GDP (*as of 2005*). In an effort to diversify its economy, the country has embarked on trading, financial, and technological industries, and most recently tourism. This has resulted into a massive construction boom. As a consequence, the demand for building materials such as ready mixed concrete, reinforced steel, and stone cladding rapidly increased. The mining sector of the UAE is also playing an important role to meet the current demands for building materials. The quarries and crushers companies based in the Emirate of Fujairah and the Emirate of Ras Al Khaimah are currently supplying the UAE with the limestone quantities that meet the demand in the country. Due to the vast growth in construction and other infrastructural activities in the UAE especially with the recent developments in the Abu Dhabi residential and commercial sectors, the demand for building materials is expected to be doubled.

It is projected that in order to fulfil demand for the building materials (which will be taken from the rocks) the process will result in the vast depletion of the natural (non-renewable) resources of the UAE. Subsequently, the demolition process will lead to the generation of more C&D waste, which if not reused or recycled, will increase the burden on the landfills in the UAE in addition to other factors such as the costing for the procurement virgin raw materials at high cost and the costing for transportation of C&D waste to landfill as well as the environmental impact of vehicle emissions and also the pressure from the environmental agencies (e.g. the Environmental Agency – Abu Dhabi) to look for alternatives that would promote environmental sustainable development.

4.1 Al Ain Crushing and Demolition Treatment Plant

In December 2oo8, the Government of Abu Dhabi established the Center of Waste Management - Abu Dhabi (CWMAD or Center) with the mandate of handling all waste management matters in the Emirate of Abu Dhabi. The C&D waste processing plant project was awarded in Al Ain in December 2008 and the project was commenced in March 2011.

The crushing plant for Al Ain was proposed by the municipality to process the construction and demolition waste generated from the construction activities in Al Ain and its region. It was also a requirement from environmental perspective that the construction waste should be processed in order to divert large amount of waste from going to the landfill and disposal sites. The plant capacity of a minimum 2000 tons/day was estimated in accordance to the number of construction projects and activities and estimated quantities during the year 2006.

The design of the proposed plant from Caldehusa-Spain has a capacity of treating 3520-7040 tons/day as mentioned in the technical specifications of their submittal. However, the contractor has planned its equipment and manpower based on the contractual requirements of processing 2000 Tons/day.

The C&D waste crushing plant project was developed with the purpose of segregating and transforming the C&D wastes in order to obtain ballasts and filling materials thereby reusing and recycling the C&D waste for conservation of natural resources and fulfilling the increasing demand of building materials. Careful review of the requirements and the processes needed was done to select the best options based on Best Available Techniques (BAT) and Best Environmental Practices (BET) in C&D waste processing using top-tier “state of the art” technologies. The plant is unique in that the process is able to process two different types of materials depending on the degree of contamination, as follows:

- C&D waste mixed with other wastes like metals, plastics etc.; and
- “Clean” construction & demolition wastes/ road excavated waste

For the project, the C&D waste and road excavated waste is being delivered to the Crushing Plant through external collectors and transporter. The final processing products are four different sizes of aggregates, recycled steel, plastic, paper, wood etc. The process is started with the inspection of the waste carrying vehicle and only authorized waste vehicles carrying acceptable waste are allowed to enter in the facility. Weighing is done at the gate and necessary information is recorded. Then-after depending on type of waste, trucks are diverted towards unloading area. Oversize (more than 200mm) wastes are broken into small pieces by the jackhammer before loading into the primary and secondary feeders. Steel is removed through powerful electromagnetic systems and other impurities such as wood, paper and plastics are removed through manual segregation at the sorting cabins. Different sizes of aggregates are then screened thorough the 39 trommel and vibrating screens. Aggregates of size more than 80mm are subject to further sorting in the secondary sorting cabin and are subsequently crushed through the impact crusher to produce sizes of desired aggregates. After crushing, the aggregates are also passed through a magnetic separator to remove embedded steel before screening through vibrating screens. Finally, the aggregates of different sizes are stockpiled under conveyor belts and then transferred to stockpile area.

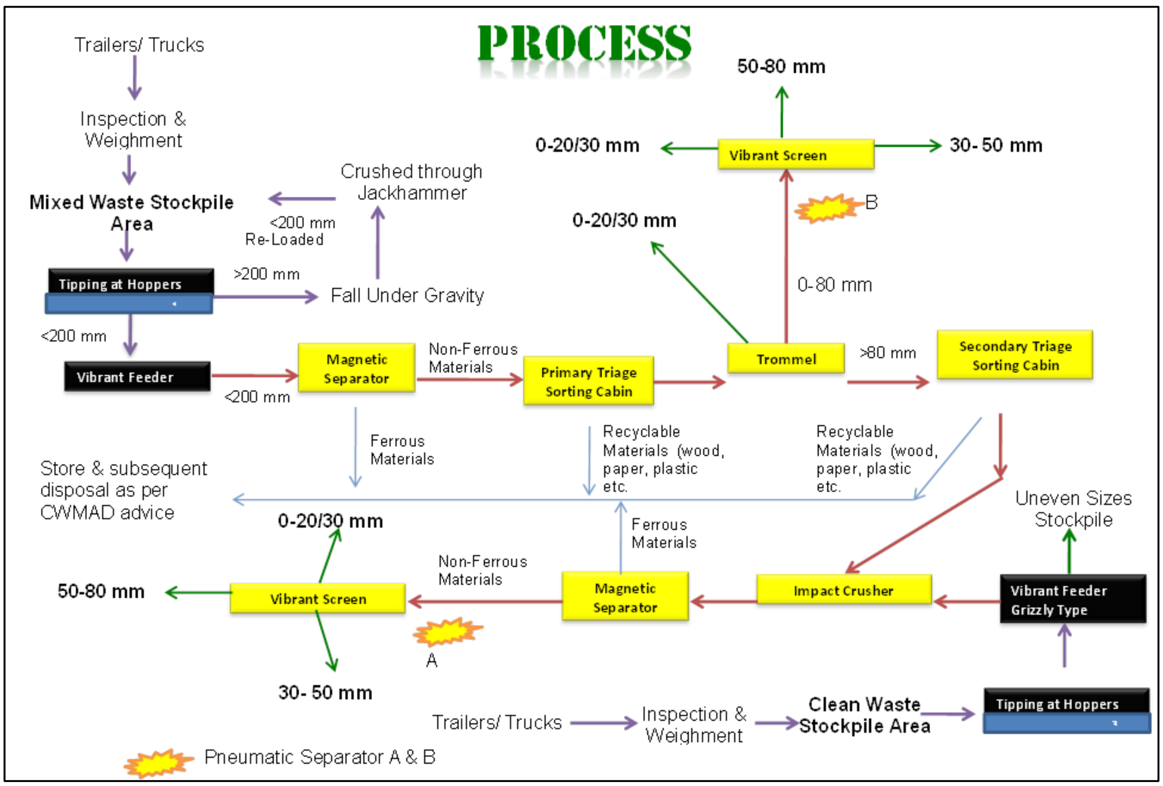

Figure 8: Process flow of the Al Ain C&D waste treatment plant

4.2 Payment of Crushing and Demolition Treatment Plant Construction

The total cost of the project is AED 173,229,934.30 and the contract duration is 20 years. It is a (BOT) contract where the government bear the full cost of the project, and the contractor will build the plant according to the contract condition and specification, and perform the operation as agreed, and transfer the plant to the client at the end of the contract. There are three main components in crushing plant payment option and is explained as follows:

1. All civil works: The payment shall be made on progressive basis based on identification of different components of civil/mechanical works to be submitted in the execution drawings of the plant and the facilities along with the Bill of Quantities (BOQ).
2. Plant, Equipment & Vehicles (Mechanical works): Same as above.
3. Management of operation, Maintenance, monitoring & Control: To be paid on monthly basis over a period of 20 years after the commissioning of the crushing plant and its operation.

The result of processing the C&D waste is the recycled aggregates and the recyclable materials. Both outcomes are saleable and form a source of revenue.

4.3 Source of Revenue

1. **Selling aggregates and recyclables**

The price of the aggregates and the recyclables keeps on changing all the time. Also, the cost of producing aggregates at a lower price depends upon the quantity of C&D waste generation and its' processing within the same allocated budget. In order to compete with the pure aggregates being sold in the market, the quality of the processed aggregates shall have to be of a similar quality and a lower price. The approximate price of the pure aggregates being sold in the market is between eighteen to twenty AED (18 - 20).

The recyclables likely to be segregated during the process are steel, metal, plastic, wood, cardboard etc. However, it is difficult to estimate the quantity of the recyclables likely to be generated from the waste as the type and quantities of C&D waste can vary widely from a project to other.

Finding a market for the aggregates and the recyclables is the responsibility of the contractor. However, the contract document does not specify a minimum quantity to be sold or minimum revenue to be generated by the contractor. Also the incentives of 5% of the gross sale of the product is not enough to motivate the contractor to look for a buyer.

2. Revenue from Tipping Fee

There is no precedent available with respect to the collection of tipping fee for the C&D waste in UAE or in the Middle East. In North America and in other parts of the world the rate has increased quite significantly in the last few years. It is in the range of US$ 4.90 to US$ 32.00 per Ton.

A reasonable flat rate per ton shall be defined to start with the idea of collecting revenue from the builders. The amount collected can be used to offset the cost of processing C&D waste, thus resulting into a reduced price of processed aggregates making it compete able with the pure aggregates available in the market.

The revenue likely to be generated from the tipping fee based on received quantity of C&D waste will result in reducing the price of saleable aggregates to compete with the cost of pure aggregates.

4.4 Cost recovery scenarios of Al Ain C&D plant

Although the consultant report has provided the necessary technical information, such as current C&D waste quantity, future projection, the technical specification of the aggregates, however, the financial aspects were not discussed. Despite the contract value and duration, neither the sales mechanism of the aggregates and recyclables, nor the cost recovery were thoroughly studied.

Therefore, the costing of processing the C&D waste and the aggregates to be produced from the waste is conducted in order to evaluate the period required for the Return of Investment. This includes all source of revenues; namely, the sale of aggregates, recyclable materials, and the revenue likely to be generated from the Tipping Fees paid by the builders and developers.

The parameters of the developed financial model provides different scenarios in terms of necessary duration to recover the cost based on the revenue generated by aggregates, recyclables, and tipping fees. The analysis statistics may change significantly depending upon the construction activities in the region and the fluctuation of the price of aggregates and the recyclables. However, since the aim of the study is to optimize the cost recovery and improve the financial effectiveness of the project, thus, the return of total investment as per the above sources of revenue shall be completed over the contractual period of 20 years.

The different scenarios and the findings are discussed below. The discussion focuses on the assumptions of each parameter and the required period for the cost recovery of the plant.

4.4.1 Basic Scenario

This scenario is based on the consultant report including the projections and the estimated sale price of both recyclables & aggregates. According to the basic assumptions the sale price of recyclable materials is variable, and the average sale price of aggregate is AED (18.25). Table 4.4.1-1 shows the different types of recyclables, the percentage, and the unit sale price of each type. In addition, the quantity of saleable aggregate is approximately 37 % of the total aggregates produced. Table 4.4.1-2 shows the different type of produced aggregates based on its size, the percentage, and the unite sale price of each size.

The revenue generated from selling both recyclables and aggregates was calculated as the following equation:

Total revenue from recyclables = received C&D waste quantity * % of recyclables * unit selling price
Total revenue from aggregates = received C&D waste quantity * % of aggregates * unit selling price

Based on the basic assumptions, the revenue generated from selling the recyclables consists 36.1%, and the revenue generated from selling the aggregates consists 63.9% of the total revenue.

Table 4.4.1-1: Basic assumption for the recyclables

RECYCLABLES	Sales %	Daily Sales (Tons/Day)	Unit Price (Dhs/Ton)
Ferrous	0.445%	8.90	600.00
Plastic	0.060%	1.20	300.00
Plastic Film	0.011%	0.22	200.00
Wood	1.356%	27.12	0.00
Paper Cardboard	0.334%	6.68	290.00
TOTAL SALES OF RECYCLABLES	2.21%	44.12	

Table 4.4.1-2: Basic assumption for the aggregates

AGGREGATES	Sales %	Daily Sales (Tons/Day)	Unit Price (Dhs/Ton)
Fraction 0-30 mm Trommel	21.00%	420.00	0
Fraction 0-20 mm Screen	19.88%	397.60	0
Fraction 20-50 mm Screen	22.72%	454.40	19.00
Fraction >50 mm Screen	14.19%	283.80	17.50
TOTAL SALES OF AGGREGATES	77.79%	1,555.80	

Based on the above mentioned projections, the total revenue throughout the contract duration is AED 133,220,938 and the break-even will be achieved in twenty six (26) years if the plant operates at full capacity of 2,000 tons/day and there is no sale market for (i) the 0-30 mm trommel fraction where the unit price is zero and the material is used as landfill cover and (ii) the 0-20 mm screen fraction where the unit price is zero and the material is also used as landfill cover.

4.4.2 Assumptions based scenarios

The C&D Plant commenced the operation in March 2011. The historical data since the commencement day shows several deviation/differences between the basic assumptions and projections, and the real actual situation. Table 4.4.2-1 shows the comparison between the projections and the actual sale price of the recyclables. Based on the projections, four (4) types of recyclable were saleable, namely ferrous, plastic, plastic film, and paper Cardboard, whereas the actual saleable recyclable is only ferrous. However, the average sale price of the ferrous remains unchanged.

On the other hand, as shown in table 4.4.2-2, two (2) types of the aggregates were assumed saleable, namely fraction 20-50 mm screen and fraction >50 mm screen, whereas the actual saleable aggregate are fraction 0-30 mm trammel, fraction 0-20 mm screen, and fraction 20-50 mm screen. The sale price of the aggregates is dependent on the unit sale price of the pure material in the market.

Table 4.4.2-1: Projected sale price vs. Actual sale price for the recyclables

Recyclable Type	Projected Sale Price (AED/ton)	Actual Sale Price (dhs/ton)
Ferrous	600.00	600.00
Plastic	300.00	0.00
Plastic Film	200.00	0.00
Wood	0.00	0.00
Paper Cardboard	290.00	0.00

Table 4.4.2-2: Projected sale price vs. Actual sale price for the aggregates

Aggregate Size	Projected Sale Price (AED/ton)	Actual Sale Price (AED/ton)
Fraction 0-30 mm Trommel	0	12.00
Fraction 0-20 mm Screen	0	12.00
Fraction 20-50 mm Screen	19.00	12.00
Fraction >50 mm Screen	17.50	0

4.5 Details of Scenarios and Findings

In order to identify the cost recovery scenarios using the developed model, several assumptions were considered for received C&D quantities per day, sale price of aggregates, and tipping fees.

- The assumption for daily C&D quantities are: five hundred (500) tons, one thousand (1000) tons, one thousand and five hundred (1,500) tons, and two thousand (2,000) tons.
- The current sale price of the pure material is AED eighteen (18). Due to resistance to the recycled aggregate and to encourage the market for buying the recycled aggregate, the starting sale price was defined to be AED twelve (12). As an assumption for developing different scenarios, four (4) sale price is selected; AED twelve (12), AED fourteen (14), AED sixteen (16), and AED eighteen (18).
- The assumptions for the charged tipping fees per ton of C&D waste received are: zero (0), AED five (5), AED ten (10), and AED fifteen (15).

Scenario 1: Figure 9 shows the revenue as a function of the C&D waste received quantity for the combined aggregates produced and the combined recyclables produced in the construction and demolition waste treatment plant. The revenue is compared as a function of the C&D waste received quantity for no charged tipping fee. Figure 9 shows that the revenue increases as a function of the construction and demolition waste received quantity for each of the combined aggregates produced and combined recyclables produced. Comparing the revenue profiles for the various construction and demolition waste received quantities for the combined aggregates produced and the combined recyclables produced shows that the revenue for the combined aggregates produced is marginally higher than that of the combined recyclables produced. The percentile quantity of combined aggregates produced (63.6%) is higher than that of the combined recyclables produced (0.45%) with the remainder of the construction and demolition waste process going for landfilling. Despite the percentiles, the revenue of the combined recyclables produced which has market sale value (ferrous only) is considerably less than that of the combined aggregates produced.

Considering the four (4) different assumptions for the received quantities, and the four (4) different assumptions for the sale price of the aggregates, sixteen (16) probabilities are estimated in terms of total revenue in which only one (1) will achieve the breakeven in approximately twenty (20) years.

On the other hand, the ratio of the revenue generated from the sale of recyclables to the revenue generated from the sale of aggregates is approximately 1:4.

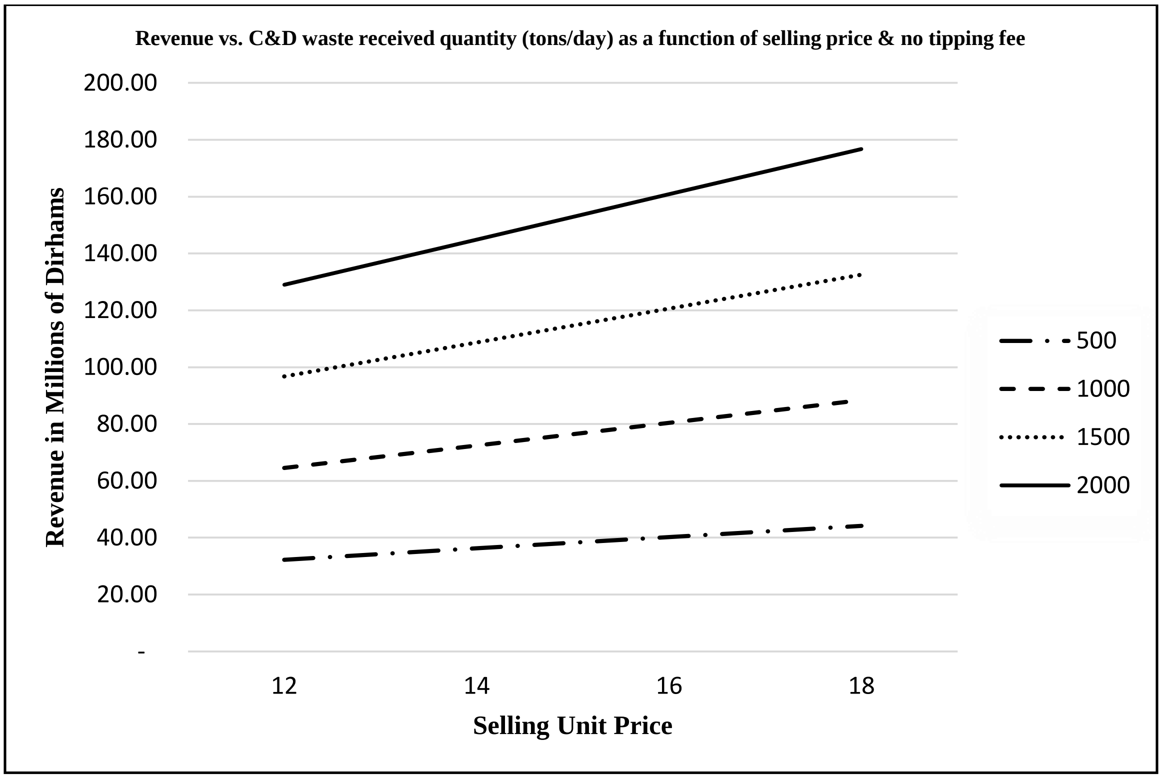

Figure 9: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (0) TP

Scenario 2:

Figure 10 shows the revenue as a function of the construction and demolition waste received quantity for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The revenue is compared as a function of the construction and demolition waste received quantity for the fixed charged tipping fee of AED 5 per trip. Figure 10 shows that the revenue increases as a function of the construction and demolition waste received quantity for each of the combined aggregates produced and combined recyclables produced. Comparing the revenue profiles for the various construction and demolition waste received quantities for the combined aggregates produced and the combined recyclables produced shows that the revenue for the combined aggregates produced is marginally higher than that of the combined recyclables produced. The percentile quantity of combined aggregates produced (63.6%) is higher than that of the combined recyclables produced (0.45%) with the remainder of the construction and demolition waste process going for landfilling. Despite the percentiles, the revenue of the combined recyclables produced which has market sale value (ferrous only) is considerably less than that of the combined aggregates produced.

In this scenario, one (1) probability is estimated to achieve the breakeven in approximately twenty (20) years and four (4) are estimated to achieve the return on investment in less than twenty (20) years.

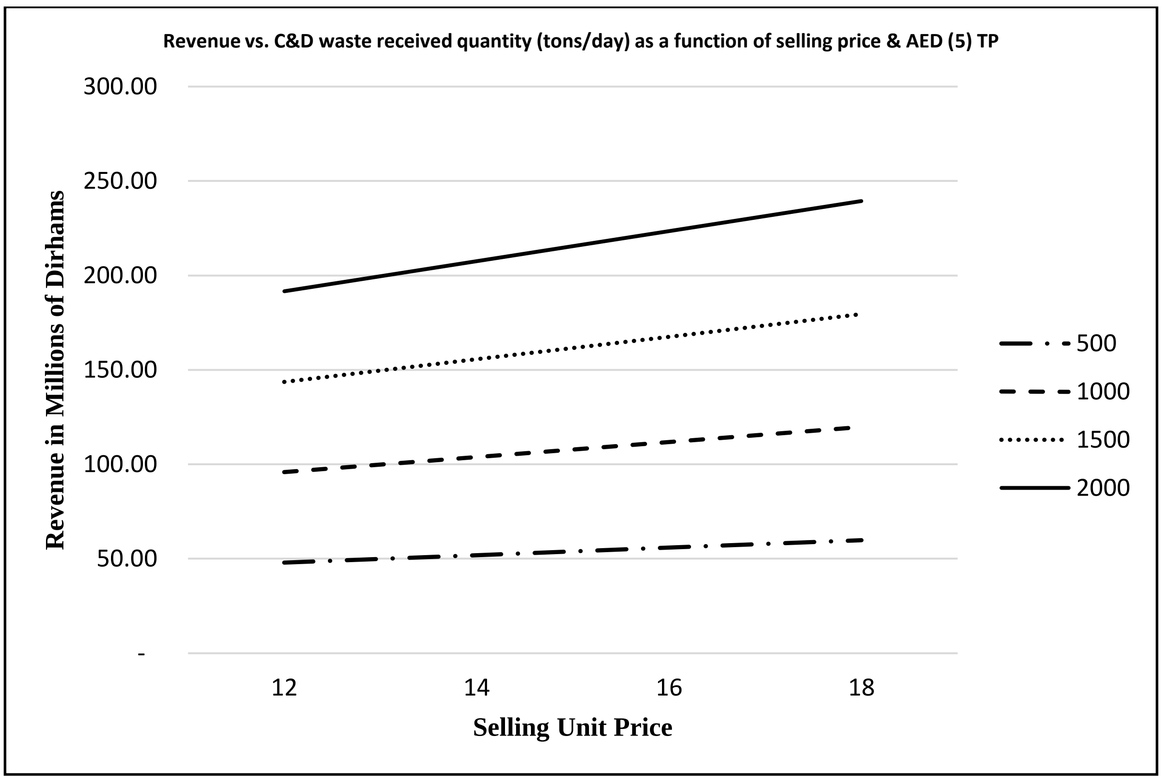

Figure 10: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (5) TP

Scenario 3: Figure 11 shows the revenue as a function of the construction and demolition waste received quantity for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The revenue is compared as a function of the construction and demolition waste received quantity for the fixed charged tipping fee of AED 10 per trip. Figure 11 shows that the revenue increases as a function of the construction and demolition waste received quantity for each of the combined aggregates produced and combined recyclables produced. Comparing the revenue profiles for the various construction and demolition waste received quantities for the combined aggregates produced and the combined recyclables produced shows that the revenue for the combined aggregates produced is marginally higher than that of the combined recyclables produced. The percentile quantity of combined aggregates produced (63.6%) is higher than that of the combined recyclables produced (0.45%) with the remainder of the construction and demolition waste process going for landfilling. Despite the percentiles, the revenue of the combined recyclables produced which has market sale value (ferrous only) is considerably less than that of the combined aggregates produced.

In this scenario, eight (8) probabilities are estimated to achieve the return on investment in less than twenty (20) years.

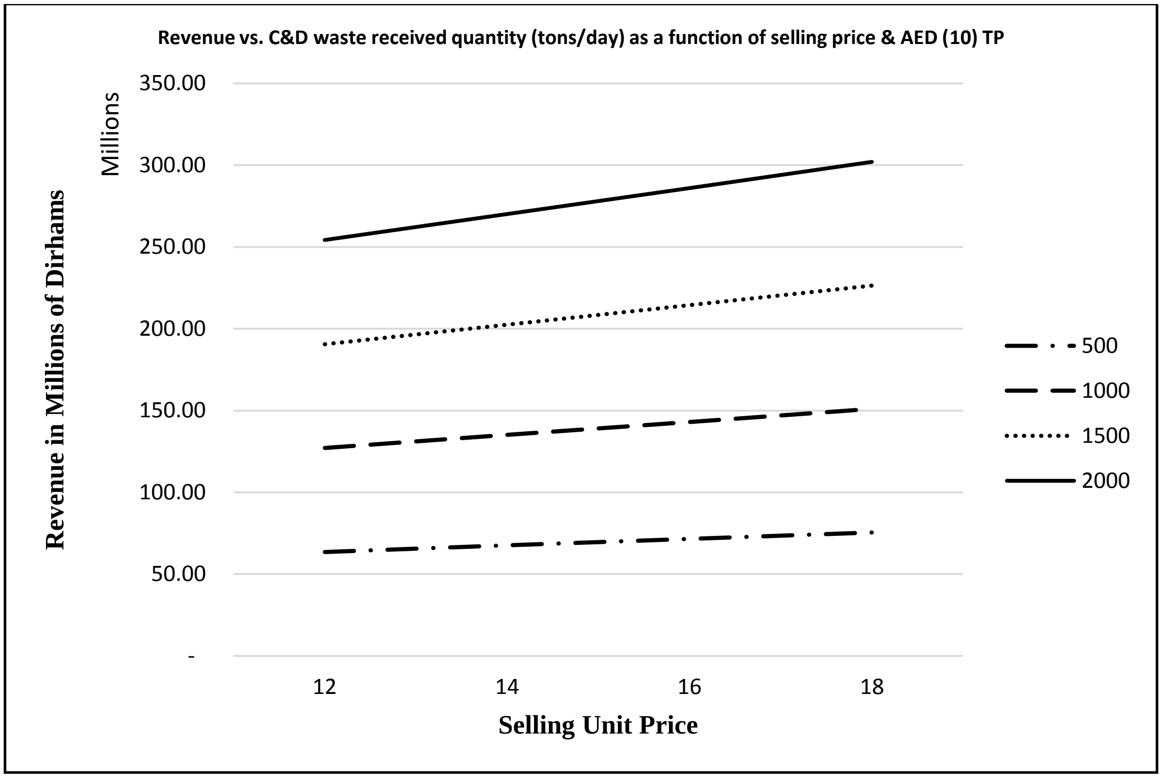

Figure 11: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (10) TP

Scenario 4: Figure 12 shows the revenue as a function of the construction and demolition waste received quantity for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The revenue is compared as a function of the construction and demolition waste received quantity for the fixed charged tipping fee of AED 15 per trip. Figure 12 shows that the revenue increases as a function of the construction and demolition waste received quantity for each of the combined aggregates produced and combined recyclables produced. Comparing the revenue profiles for the various construction and demolition waste received quantities for the combined aggregates produced and the combined recyclables produced shows that the revenue for the combined aggregates produced is marginally higher than that of the combined recyclables produced. The percentile quantity of combined aggregates produced (63.6%) is higher than that of the combined recyclables produced (0.45%) with the remainder of the construction and demolition waste process going for landfilling. Despite the percentiles, the revenue of the combined recyclables produced which has market sale value (ferrous only) is considerably less than that of the combined aggregates produced.

In this scenario, one (1) probability will achieve the breakeven in twenty (20) years, and nine (9) probabilities are estimated to achieve the return on investment in less than twenty (20) years.

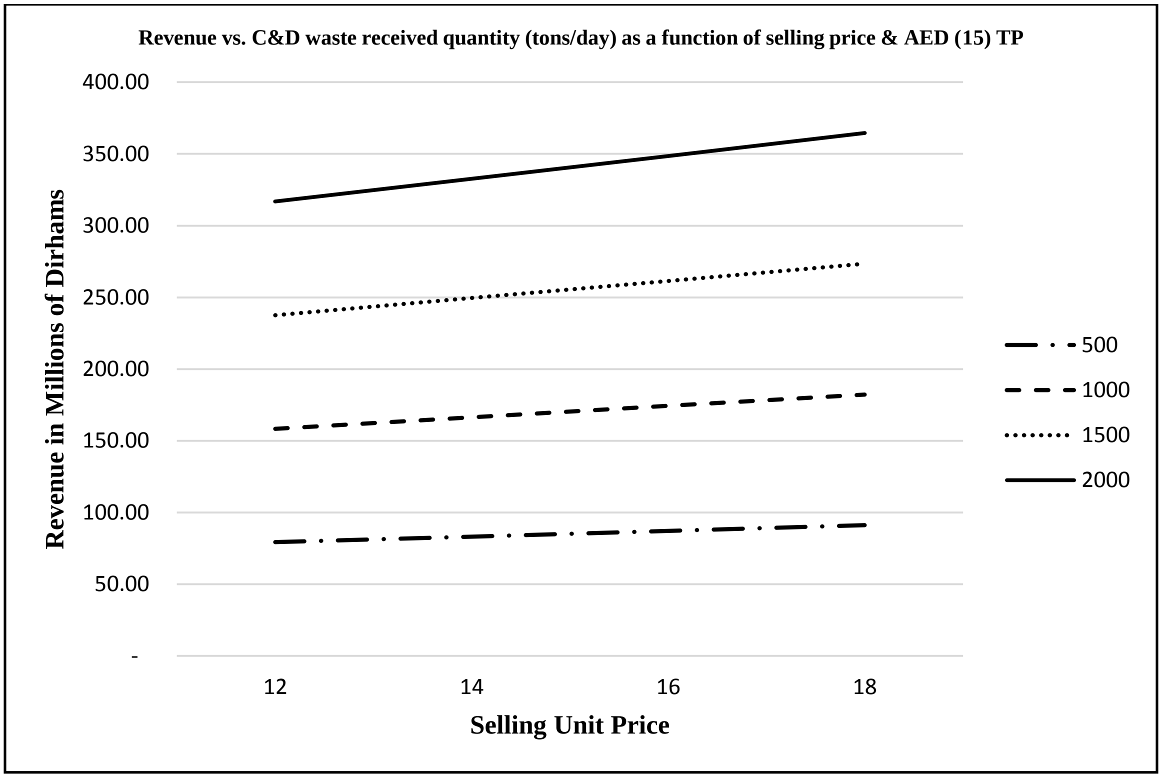

Figure 12: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (15) TP

Scenario 5: Figure 13 shows the revenue as a function of the sale price for the combined aggregates produced in the construction and demolition waste processing plant. The revenue is compared as a function of sale price for the fixed construction and demolition waste received quantity of 500 tons/day. The revenue is compared as a function of sale price for the various charged tipping fee values illustrated above. A similar argument to that of the sale price for the combined recyclables produced in the construction and demolition waste processing plant is provided below. Figure 13 shows that the revenue increases as a function of sale price for the increasing charged tipping fees.

The maximum revenue generated based on this assumptions of this scenario is approximately equal to half of the total investment of the C&D treatment plant. In this scenario, none of the probabilities will achieve the breakeven in twenty (20) years.

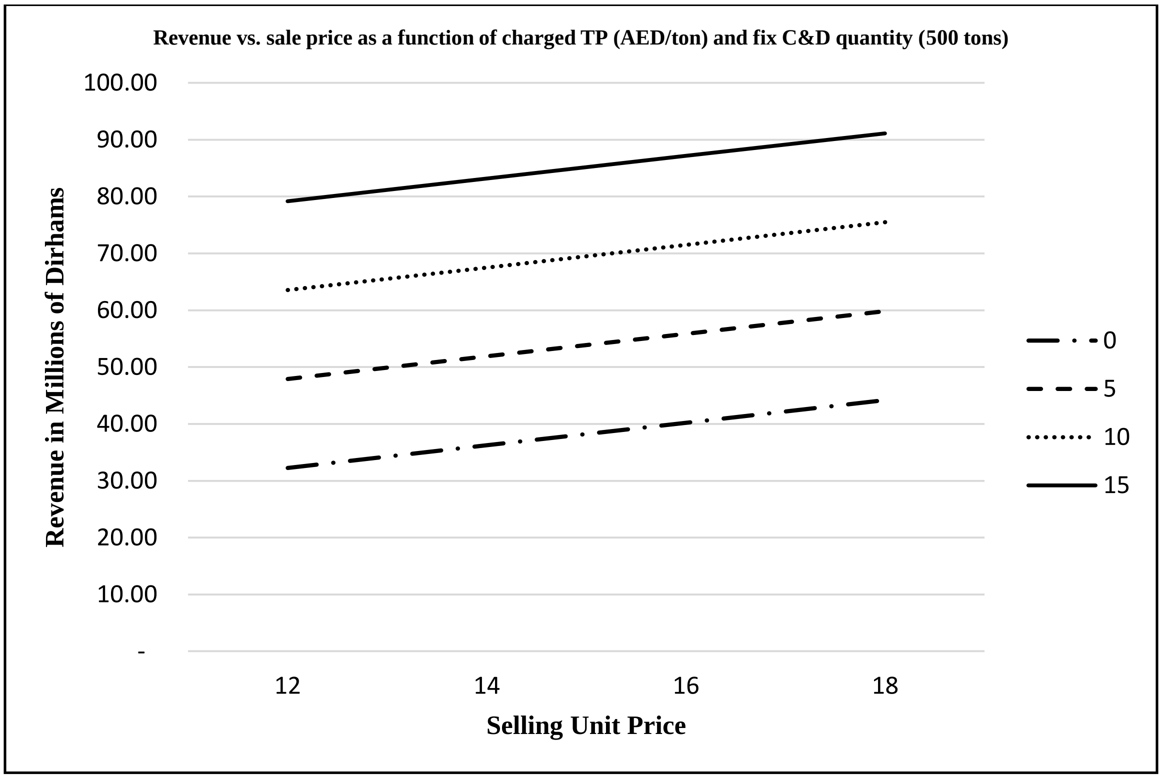

Figure 13: Revenue (AED) versus selling price (AED) as a function of charged TP (AED/ton) and fix C&D quantity (500 tons)

Scenario 6: 14 shows the total revenue as a function of the sale price for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The total revenue is compared as a function of sale price for the fixed construction and demolition waste received quantity of 1,000 tons/day. The total revenue is compared as a function of sale price for the various charged tipping fee values illustrated above. Comparing the total revenue profiles for the various charged tipping fees shows that the total revenue increases as a function of sale price for the increasing charged tipping fees.

In this scenario, one (1) probability will achieve the breakeven in twenty (20) years, and one (1) probability is estimated to achieve the return on investment in less than twenty (20) years.

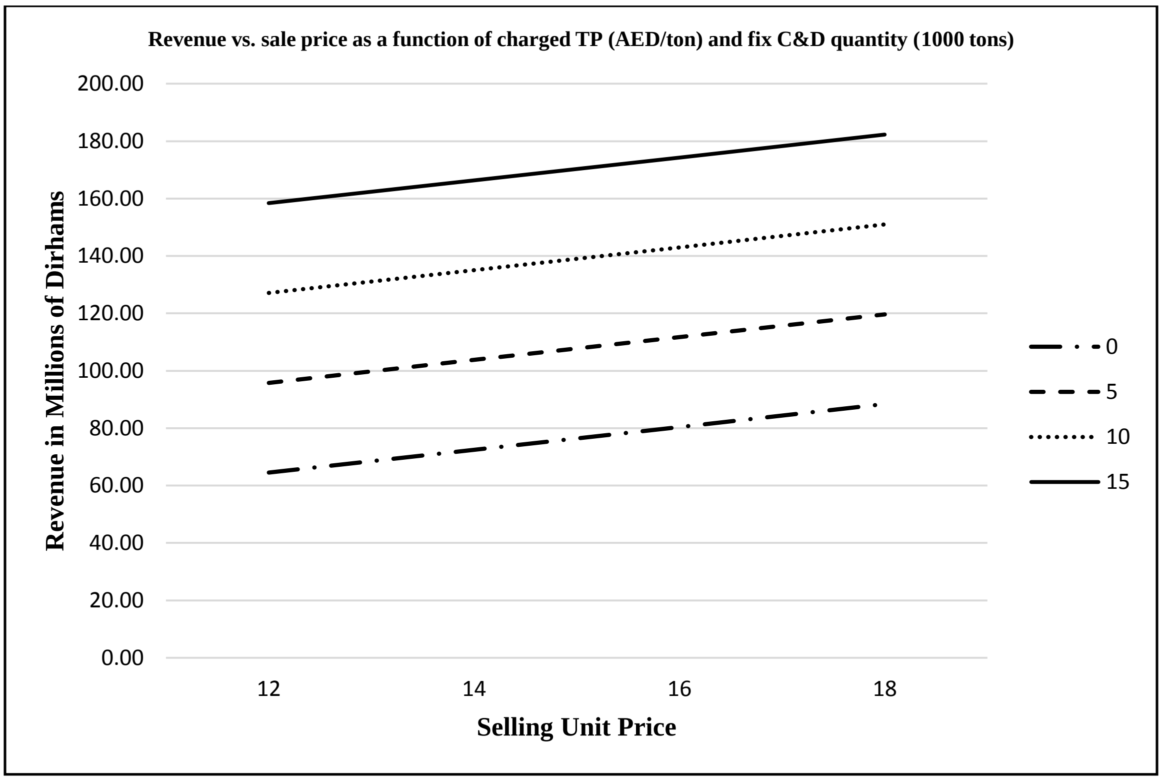

Figure 14: Revenue (AED) versus selling price (AED) as a function of charged TP (AED/ton) and fix C&D quantity (1000 tons)

Scenario 7: Figure 15 shows the total revenue as a function of the sale price for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The total revenue is compared as a function of sale price for the fixed construction and demolition waste received quantity of 1,500 tons/day. The total revenue is compared as a function of sale price for the various charged tipping fee values illustrated above. Figure 15 shows that the total revenue increases as a function of sale price for the increasing charged tipping fees.

In this scenario, nine (9) probabilities will achieve the return on investment in less than twenty (20) years.

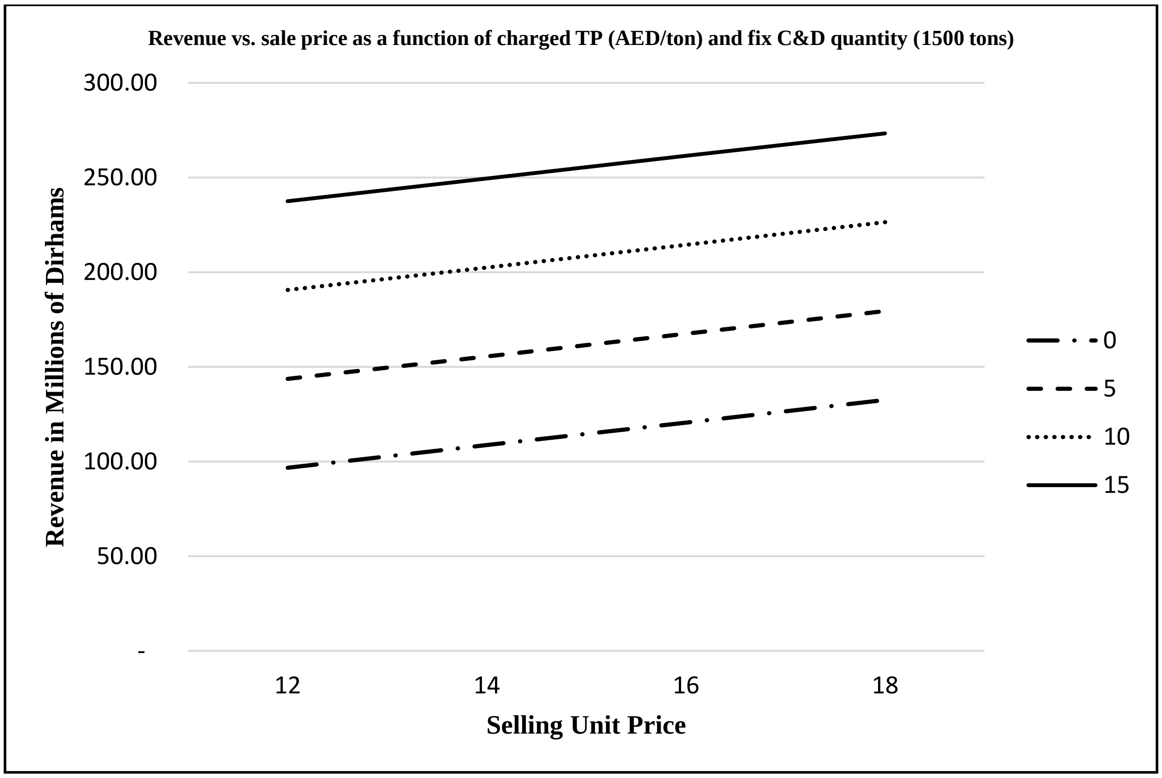

Figure 15: Revenue (AED) versus selling price (AED) as a function of charged TP (AED/ton) and fix C&D quantity (1500 tons)

Scenario 8: Figure 16 shows the total revenue as a function of the sale price for the combined aggregates produced and the combined recyclables produced in the C&D waste treatment plant. The total revenue is compared as a function of sale price for the fixed construction and demolition waste received quantity of 2,000 tons/day. The total revenue is compared as a function of sale price for the various charged tipping fee values illustrated above. Figure 16 shows that the total revenue increases as a function of sale price for the increasing charged tipping fees.

In this scenario, all the sale prices will achieve the return on investment in less than twenty (20) years if the tipping fees are charged for the received quantities of C&D waste. However, if no tipping fee is charged, the only probability to achieve the breakeven within the duration of the contract is when the sale price is AED eighteen (18).

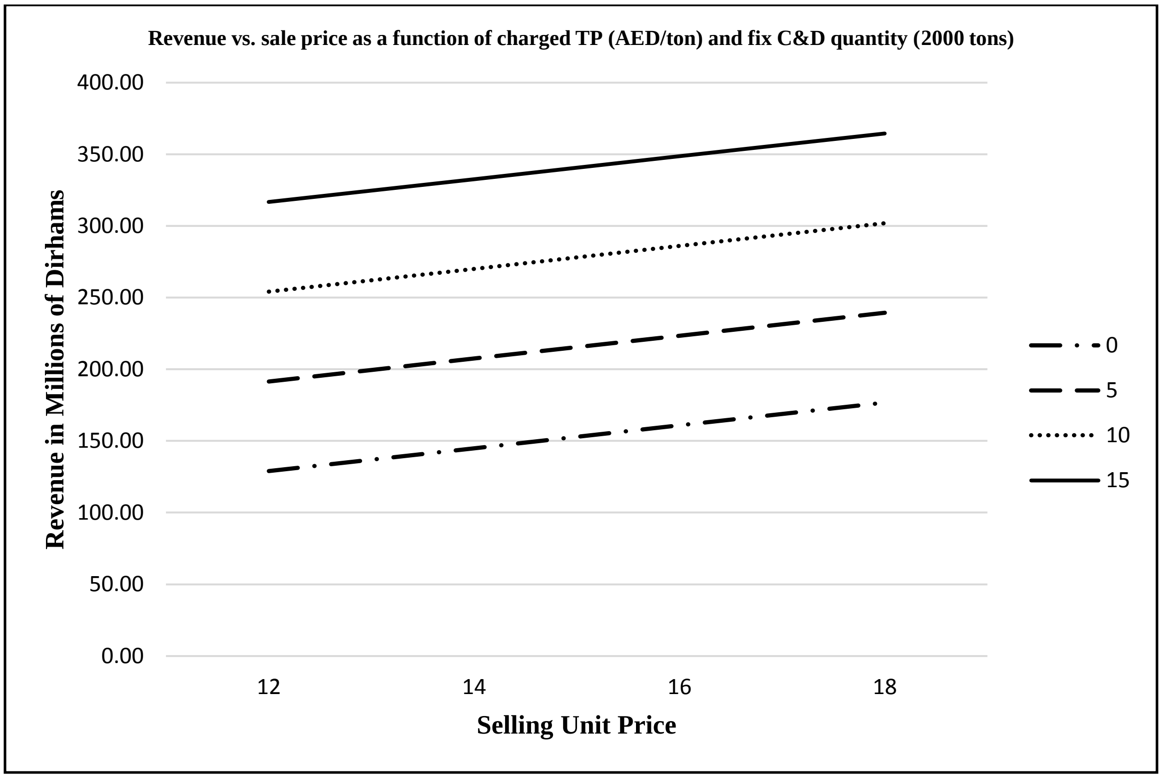

Figure 16: Revenue (AED) versus selling price (AED) as a function of charged TP (AED/ton) and fix C&D quantity (2000 tons)

Scenario 9: Figure 17 shows the revenue as a function of the sale price for only the combined aggregates produced in the C&D waste treatment plant. The revenue is compared as a function of sale price for no charged tipping fee. The revenue is compared as a function of sale price for the various construction and demolition waste received quantities illustrated above. Figure 17 shows that the revenue increases as a function of sale price for the increasing construction and demolition waste received quantities.

In this scenario, none of the probabilities will achieve the return on investment in twenty (20) years even if maximum quantity of C&D received and higher sale price of AED eighteen (18) is applied.

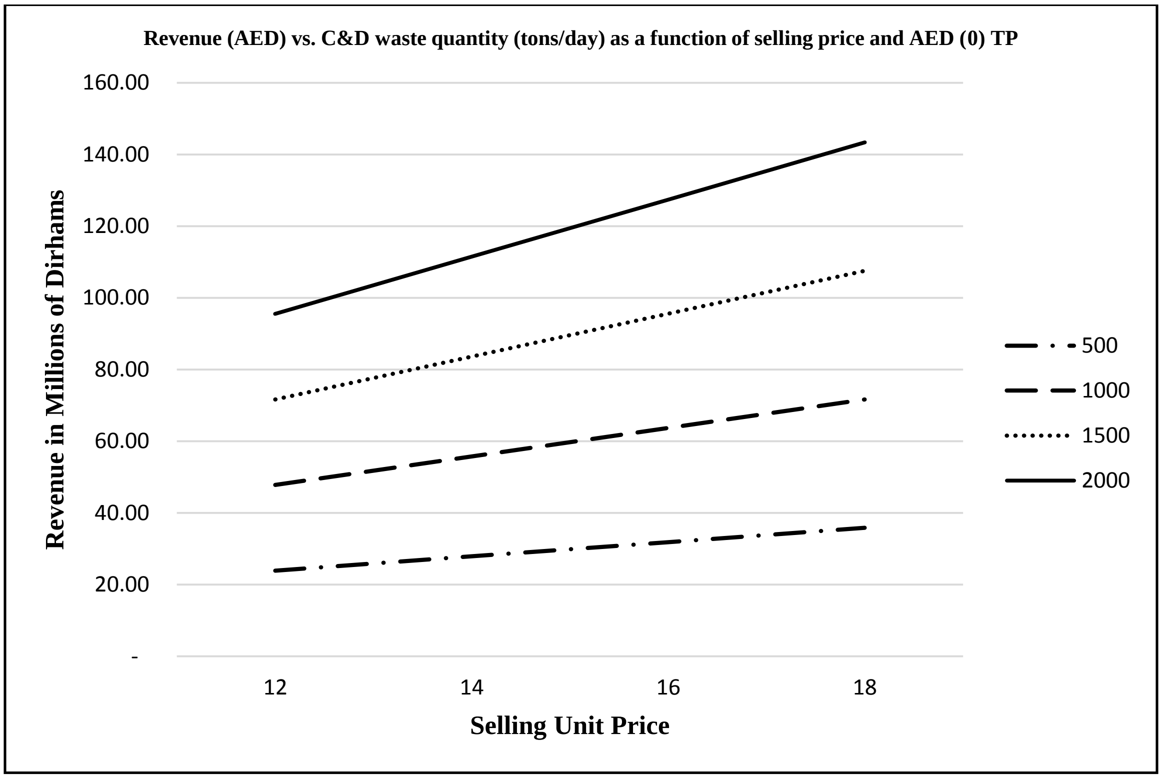

Figure 17: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (0) TP

Scenario 10: Figure 18 shows the revenue as a function of the sale price for the combined aggregates produced in the construction and demolition waste processing plant. The revenue is compared as a function of sale price for the fixed charged tipping fee of AED 5 per trip. The revenue is compared as a function of sale price for the various construction and demolition waste received quantities illustrated above. Figure 18 shows that the revenue increases as a function of sale price for the fixed charged tipping fee of AED 5 per ton. Comparing the revenue profiles for the various construction and demolition waste received quantities shows that the revenue increases as a function of sale price for the increasing construction and demolition waste received quantities. For a fixed sale price of production combined aggregates, figure 18 shows that, for an increase in the construction and demolition waste received quantities, the revenue increases with an increase in quantities of construction and demolition waste received a the processing plant.

In this scenario, one (1) probability will achieve the return on investment in twenty (20) years, and two (2) probabilities will achieve the return on investment in less than twenty (20) years.

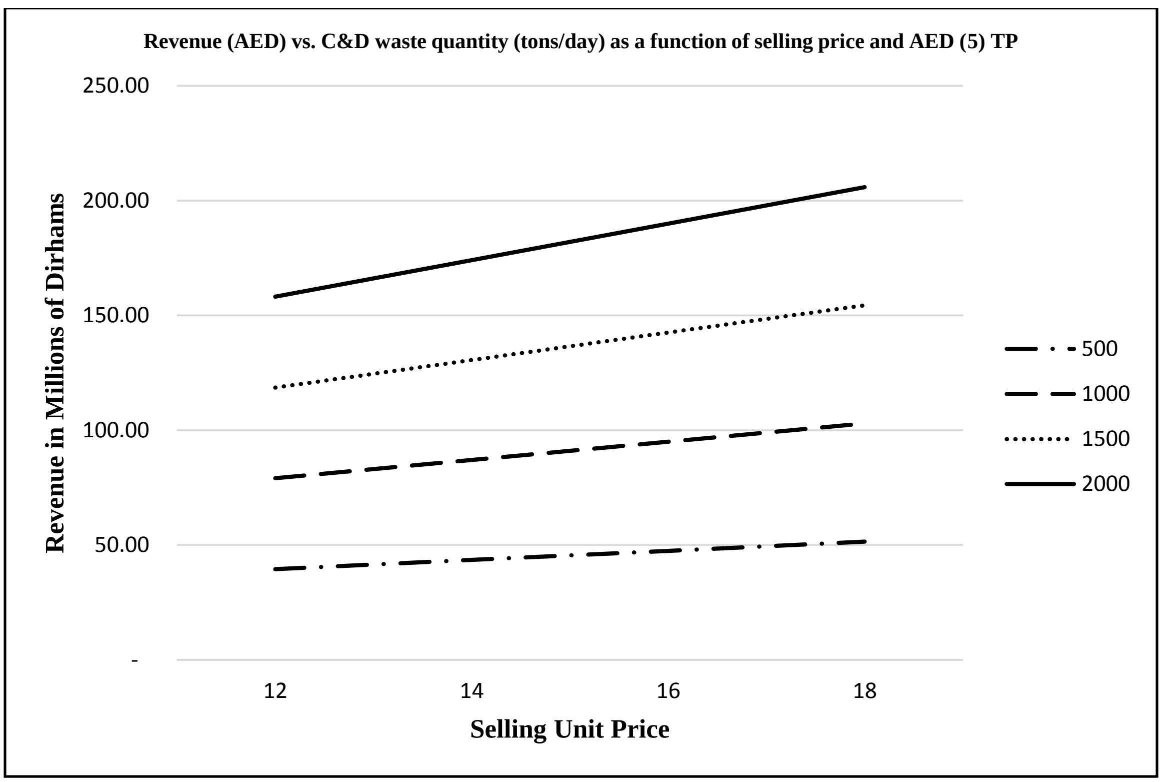

Figure 18: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (5) TP

Scenario 11: Figure 19 shows the revenue as a function of the sale price for the combined aggregates produced in the construction and demolition waste processing plant. The revenue is compared as a function of sale price for the fixed charged tipping fee of AED 10 per trip. The revenue is compared as a function of sale price for the various construction and demolition waste received quantities illustrated above. Figure 19 shows that the revenue increases as a function of sale price for the fixed charged tipping fee of AED 10 per ton. Comparing the revenue profiles for the various construction and demolition waste received quantities shows that the revenue increases as a function of sale price for the increasing construction and demolition waste received quantities. For a fixed sale price of production combined aggregates, figure 20 shows that, for an increase in the construction and demolition waste received quantities, the revenue increases with an increase in quantities of construction and demolition waste received a the processing plant.

In this scenario, seven (7) probabilities will achieve the return on investment in less than twenty (20) years. This is only when the received quantities of C&D waste are 2,000 tons/day or 1,500 tons/day and the sale price is AED fourteen (14) and above.

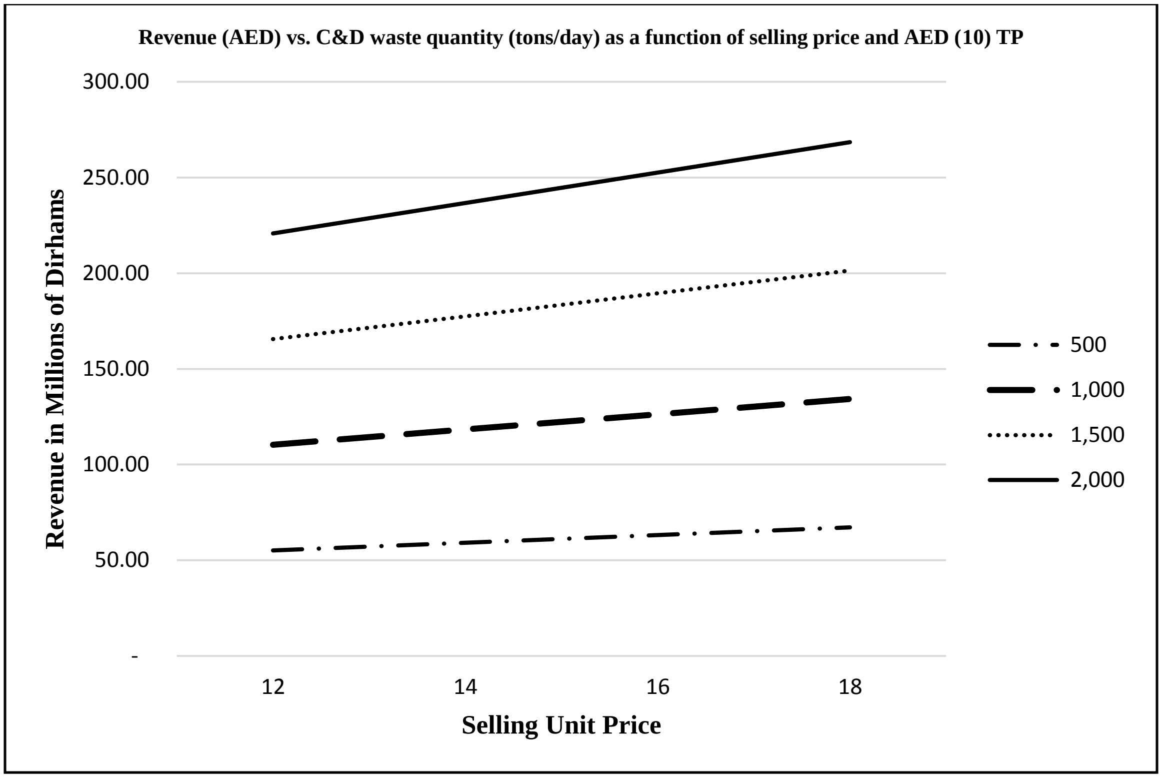

Figure 19: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (10) TP

Scenario 12: Figure 20 shows the revenue as a function of the sale price for the combined aggregates produced in the construction and demolition waste processing plant. The revenue is compared as a function of sale price for the fixed charged tipping fee of AED 15 per trip. The revenue is compared as a function of sale price for the various construction and demolition waste received quantities illustrated above. Figure 20 shows that the revenue increases as a function of sale price for the fixed charged tipping fee of AED 15 per ton. Comparing the revenue profiles for the various construction and demolition waste received quantities shows that the revenue increases as a function of sale price for the increasing construction and demolition waste received quantities. For a fixed sale price of production combined aggregates, figure 20 shows that, for an increase in the construction and demolition waste received quantities, the revenue increases with an increase in quantities of construction and demolition waste received a the processing plant.

In this scenario, eight (8) probabilities will achieve the return on investment in less than twenty (20) years. This is only when the received quantities of C&D waste are 1,500 tons/day or 2,000 tons/day.

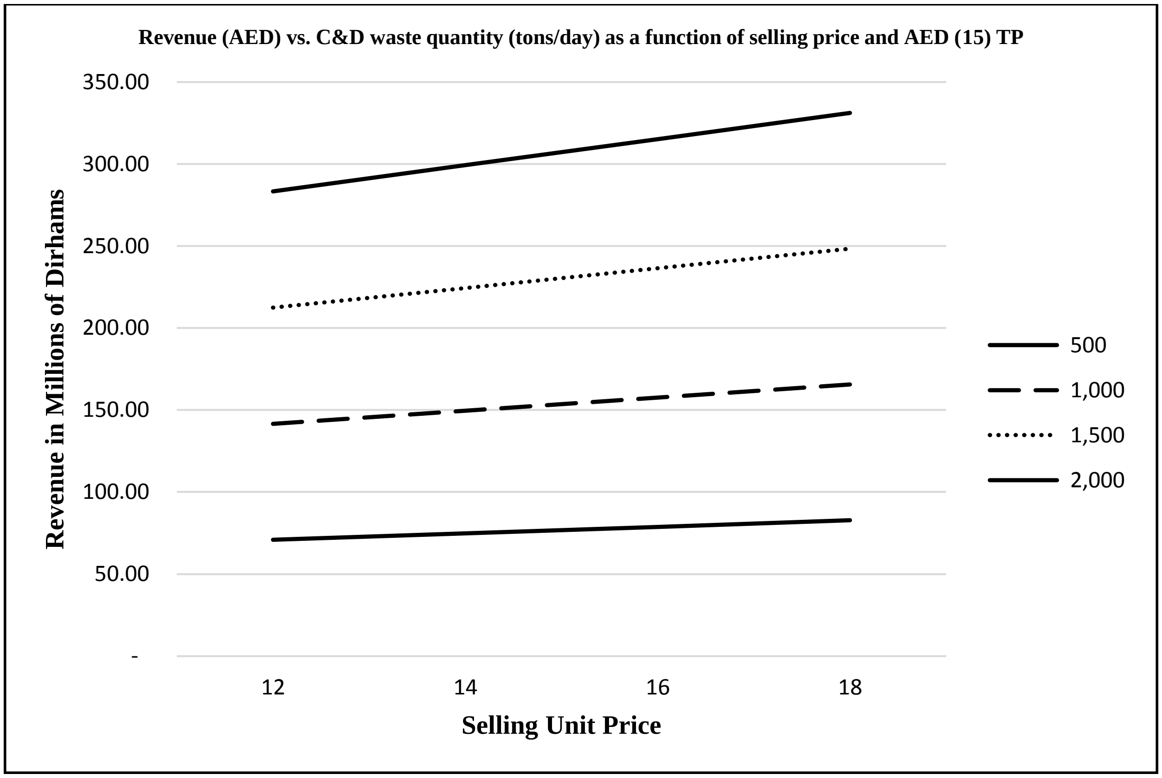

Figure 20: Revenue (AED) versus C&D waste received quantity (tons/day) as a function of selling price and AED (15) TP

Chapter 5 Discussion

5.1 C&D Waste composition

The financial success of the C&D waste treatment plants is dependent on the amount and quality of the crushing and demolition waste received. The consistency of both C&D waste quantity and composition will determine the extent of cost recovery accomplishment.

C&D waste is distinguished into different types produce from different sources or activities, such as: Construction, Demolition, Excavation, Refurbishment of houses, and Road refurbishment. However, several factors may lead to variability of C&D waste, such as: varying relevant regulations to C&D waste management industry, variety of disposal options including illegal dumping, different cost of conventional landfill disposal, and inconsistent composition of C&D waste.

5.2 Al Ain C&D waste treatment plant capacity

Al Ain plant was designed to receive 2,000 ton/day as maximum capacity. However, considering the time loss in process, maintenance, and day-offs the actual capacity is less than the theoretical 2,000 ton/day. Moreover, based on the historical data since the commencement day of the plant operation, the maximum quantity received was approximately 1,400 ton/day and the minimum quantity received was approximately 700 ton/day. Although the historical data does not present a steady trend for the daily received quantity, however, the monthly average of the received C&D waste quantities is approximately equal to the average of the highest and the lowest historical quantities. Therefore, the discussion will focus on the 1,000 ton/day as closest assumption to the actual received quaintest at Al Ain C&D waste treatment plant.

5.3 Sale Price

In order to guarantee the competitiveness of the recycled C&D material, the quality of the recycled aggregates must be assured. The pure material in the market are of an approved standard and specifications. Unacceptance or low demand on the recycled aggregates is an expected resistance to a major change in the C&D industry. Therefore, the sale price of aggregates is dependent on the sale price of the pure material.

The pure material can be obtained from several sources within Al Ain region or beyond its' borders. In order to manage and overcome the buyers' resistance at this early phase of the change, the sale price was set at approximately 75% of the pure material price. This percentage is expected to remain consistent unless changes in C&D laws and regulations are announced.

5.4 Tipping Fee

This study is an attempt toward introducing optimum cost recovery scenario of Al Ain C&D waste treatment plant and developing an integrated solution for the management of C&D waste treatment projects. However, the concept of integrated waste management solution is a combination of waste prevention / reduction, waste reuse, and enhance waste recycle. The goal of these principles is to divert wastes from landfills.

The waste hierarchy or the 3R principle is the basis of the environmentally sound strategies and most efficient guiding principle of the waste management integrated solutions. Waste reduction, reuse, and recycling are respectively the most favored option and the disposal as the least favored option in the waste management systems. The waste reduction not only assure the environmental protection, but also contributes to economic benefits. It will lead to higher amount of waste diversion from landfills (Hao et al., 2008) and subsequently lower cost of waste management bared by governments, in addition to possibility of selling specific waste material at a lower cost which enables construction firms to reduce their cost (Snook et al., 1995, and Guthrie et al., 1999). This will lead to a higher level of social / economic impact in terms of increasing the competitiveness of the construction industry (Begum et al., 2006).

(Yuan and Lu, 2010) concluded the waste management regulations and awareness of C&D waste management as critical success factors (CSFs) for developing effective C&DWM strategies.

Likewise, (Zhaoa et al. 2011) discussed the relative factors that contribute to the economic feasibility of C&D waste management. The "extra revenue" (from location advantage in his study) was identified as a major factor of economic viability.

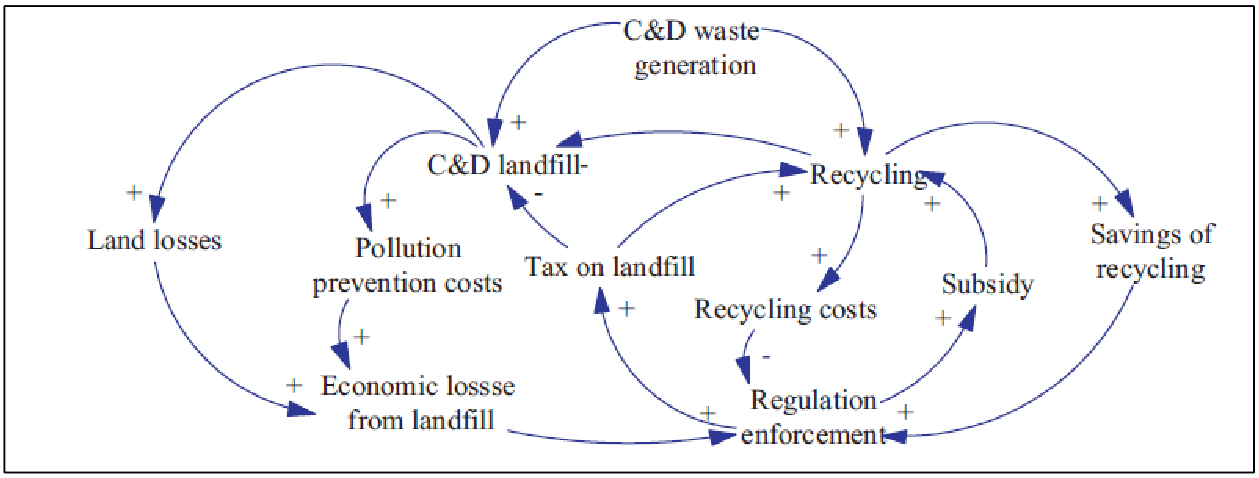

Figure 21: Casual loop diagram of C&D waste management model (Zhao et al. 2011)

5.5 Environmental impact of applying tipping fee

(Sakai et al. 2008) has surveyed the Unit-charging programs known as pay-as-you-throw (PAYT) in Japan. It is an equitable tool to both individuals and businesses in order identify the cost of solid waste services based on the amount of waste produced. It is an economy based tool with an environmental approach which has been promoted to reduce the waste generation (Ministry of the Environment, 2005a; Tanaka et al., 1996) in addition to encouraging recycling and increasing the public environmental awareness.

Imposing fee on waste disposal (PAYT) has reduced the amount of biodegradable municipal waste up to 35%. The EU's landfill directive (1999) is a clear example of encouraging waste reduction. (Price, 2001). Whilst flat rate system in Greece has been highly debated in terms of unfairness (Karagiannidis et al., 2006). Since the 1990s, PAYT has been widely recognized as an effective tool of waste management in several countries. It is considered a major economic approach to promote 3Rs concept. Case studies showed the amount of waste to reduce in some municipalities by 20-30%. (Oshima, 2006; Kusumoto, 2003).

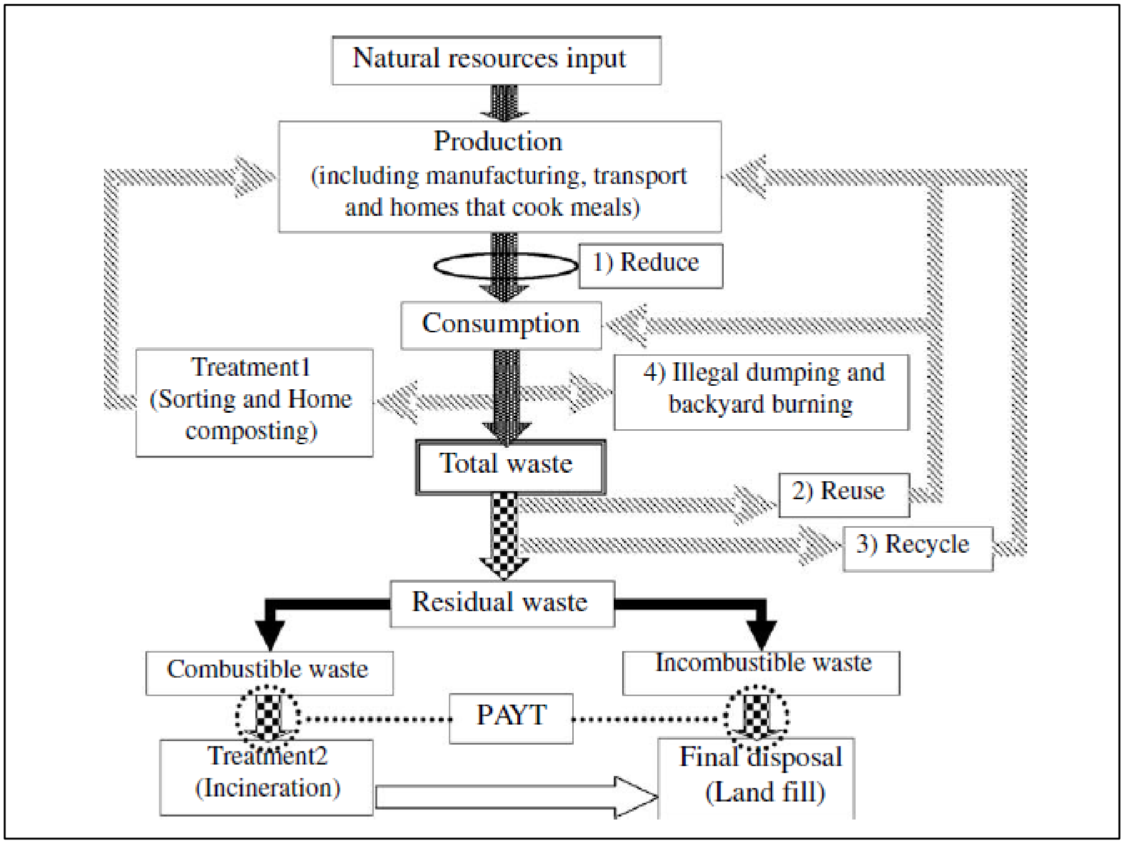

Figure 22: 3Rs (reduce, reuse and recycle) in the waste flow in Japan and its relationship with PAYT (Sakai et al. 2008)

5.6 tipping fee – cost recovery

The case findings and the scenarios elaborated that charging tipping caused significant increase in the total revenue generated. The scenarios presented in detail that regardless of the daily received C&D waste quantity, when the minimum tipping fee of AED five (5) was applied, and based on four assumptions of sale price, namely AED 12, 14, 16, and 18, the revenue generated from the tipping fee varied between 33% and 26%.

When the second assumption for the tipping fee of AED ten (10) was applied, the revenue generated from the tipping fee varied between 49% and 41%.

When the third assumption for the tipping fee of AED fifteen (15) as highest assumption was applied, the revenue generated from the tipping fee varied between 59% and 52%.

Since the tipping is charged per each ton of C&D waste, the contribution of the revenue generated by the tipping fee to the total revenue increases by the decrease in the sale price. Based on this reciprocal relationship between the charged tipping fee and the sale price, the percentage of the total revenue generated from the tipping fee increases up to approximately 7% when minimum sale price of AED 12 is applied.

On the other hand, regardless of the sale price, the percentage of the total revenue generated from the tipping fee significantly increases when a higher tipping fee is applied. Specifically, for any assumption of the sale price, the total revenue generated from the tipping fee increases by 16% when the tipping fee increases from AED five (5) to AED ten (10), and it increases by 20% when the tipping fee increases from AED five (5) to AED fifteen (15).

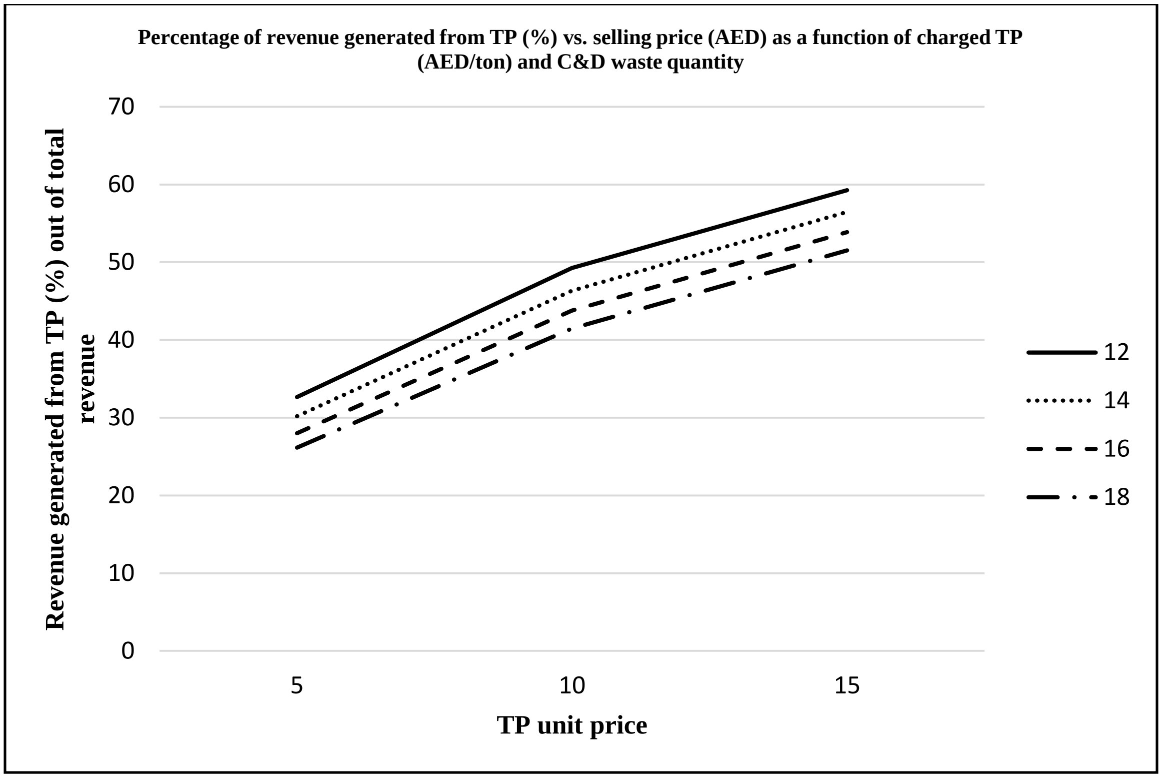

Figure 23: Percentage of revenue generated from TP (%) versus selling price (AED) as a function of charged TP (AED/ton) and C&D waste received quantity

As demonstrated by the twelve (12) scenarios, when no tipping fee is charged, the only probability in which the return on investment is achieve in twenty (20) years, is when both the highest quantity and the highest sale price are guaranteed for the all duration of the contract.

Figure 22 shows the breakeven required number of years as a function of the construction and demolition waste received quantity. The total revenue is evaluated based on the total revenue generated from (i) the sale of the combined aggregates produced and (ii) the sale of the combined recyclables produced and (iii) fixed charged tipping fee quantity of 10 dirhams/trip for each annum. The breakeven required number of years is compared as a function of the construction and demolition waste received quantity for the various total sale prices of the combined aggregates produced and the combined recyclables produced. The combined cost (CAPEX and OPEX) for the project has been set at 173 million dirhams. Therefore, the breakeven required number of years can be determined as a function of the construction and demolition waste received quantity at each total sale price of the combined aggregates produced and the combined recyclables produced. Figure 8 shows that the breakeven required number of years decreases as a function of the construction and demolition waste quantity received for the fixed charged tipping fee of 10 dirhams/ton and the fixed total sale price of the combined aggregates produced and the combined recyclables produced. Comparing the breakeven required number of years profiles for the various total sale prices of the combined aggregates produced and the combined recyclables produced shows that the breakeven required number of years decreases as a function of the construction and demolition waste quantity received for the fixed charged tipping fee of 10 dirhams/ton for the increasing total sale price of the combined aggregates produced and the combined recyclables produced. For a fixed construction and demolition waste received quantity, figure 8 shows that, for an increase in total sale price of the combined aggregates produced and the combined recyclables produced, the breakeven required number of years decreases.

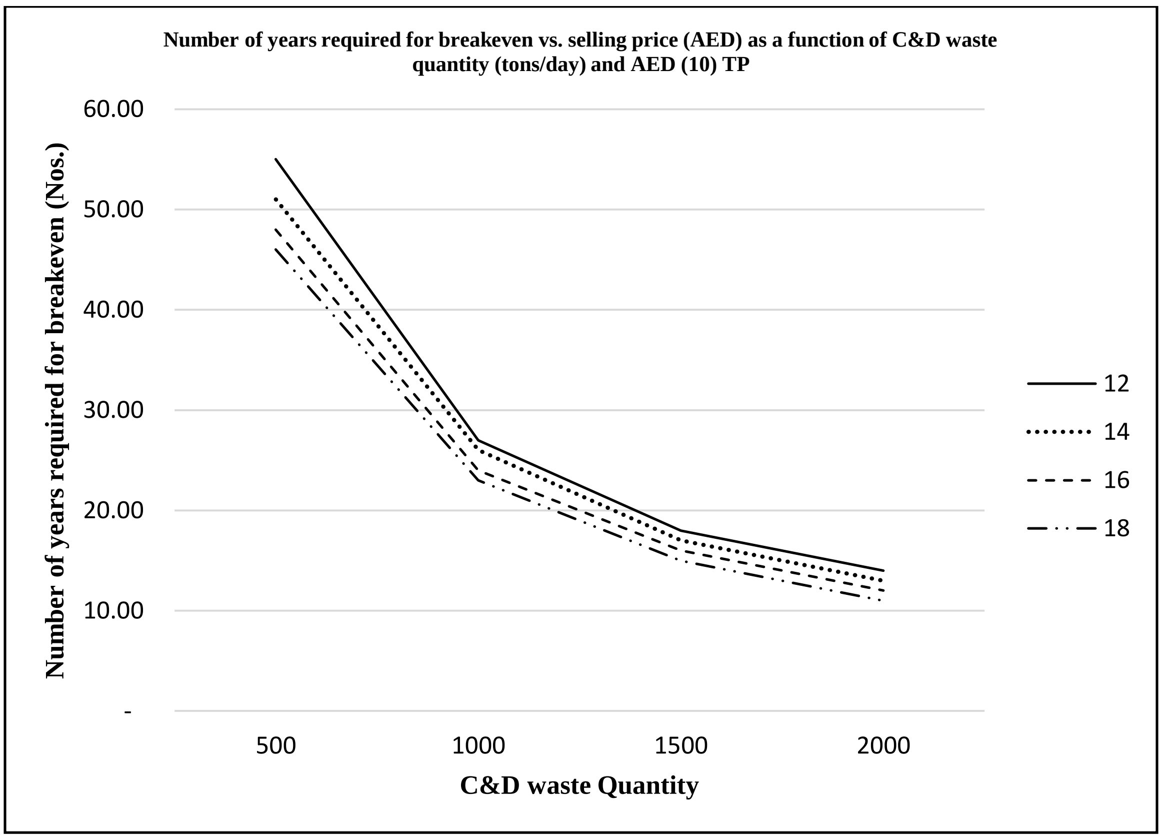

Figure 24: **Number of years required for breakeven versus selling price (AED) as a function of C&D waste received quantity (tons/day) and fixed TP of AED (10)**

Figure 9 shows the breakeven required number of years versus sale price as a function of the charged tipping fee and the C&D waste received quantity. The total revenue is evaluated based on the total revenue generated from (i) the sale of the combined aggregates produced and (ii) the sale of the combined recyclables produced and (iii) fixed demolition waste received quantity of 1000 tons/day. The breakeven required number of years is compared as a function of the charged tipping fee for the various total sale prices of the combined aggregates produced and the combined recyclables produced. The combined cost (CAPEX and OPEX) for the project has been set at 173 million dirhams. Therefore, the breakeven required number of years can be determined as a function of the charged tipping fee at each total sale price of the combined aggregates produced and the combined recyclables produced. Figure 9 shows that the breakeven required number of years decreases as a function of the charged tipping fee for the fixed demolition waste received quantity of 500 tons/day and the fixed total sale price of the combined aggregates produced and the combined recyclables produced. Comparing the breakeven required number of years profiles for the various total sale prices of the combined aggregates produced and the combined recyclables produced shows that the breakeven required number of years decreases as a function of the charged tipping fee for the fixed demolition waste received quantity of 500 tons/day for the increasing total sale price of the combined aggregates produced and the combined recyclables produced. For a fixed charged tipping fee, figure 9 shows that, for an increase in total sale price of the combined aggregates produced and the combined recyclables produced, the breakeven required number of years decreases.

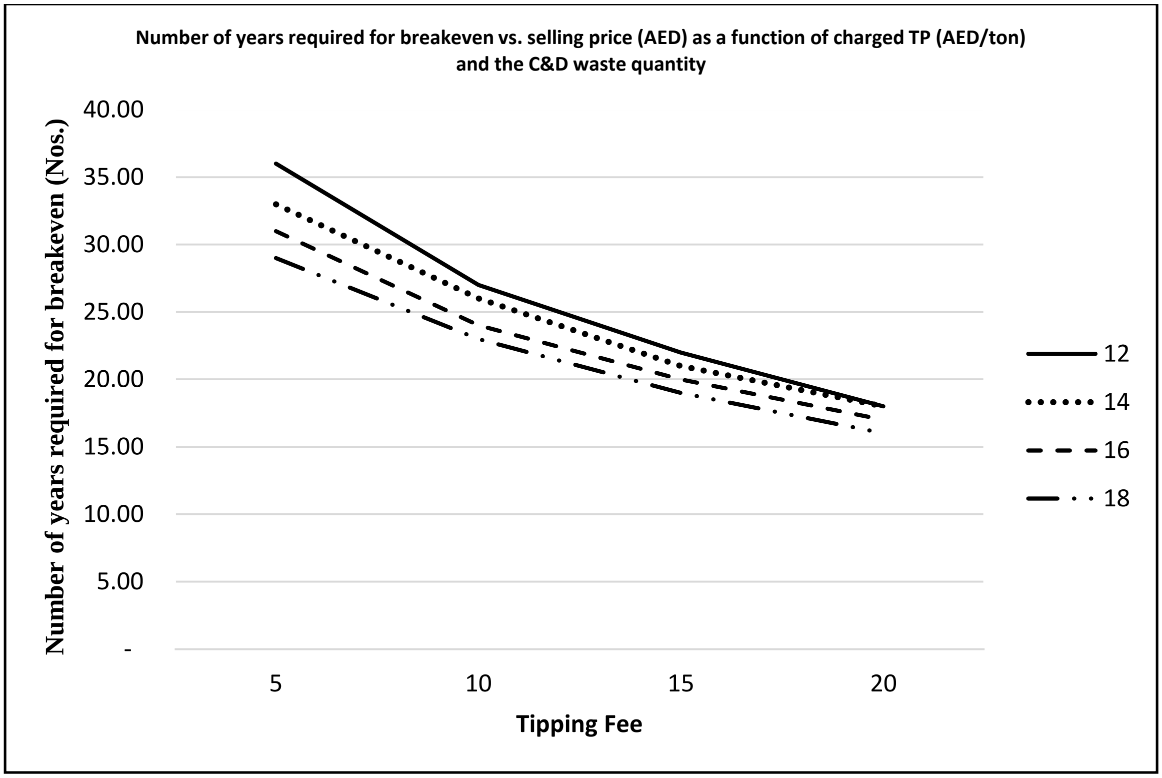

Figure 25: Number of years required for breakeven (nos.) versus selling price (AED) as a function of charged tipping fee (AED/ton) and the C&D waste received quantity

In conclusion, the construction and demolition activities determine the daily quantity of C&D waste received at the plant. Although the increase of the C&D waste quantities will increase the amount of the recycled aggregates and subsequently the sales, However, it has not been reported neither projected to exceed the maximum capacity of the plant ever since the commencement of plant operation. In addition, the reports are evident that the average quantities is approximately equal to the 50% of the maximum plant capacity. Therefore, the contribution of the C&D waste quantity to the cost recovery is not a tool for managerial decision making.

On the other hand, the sale price is a factor of less flexibility. As discussed, in order to assure sales stability, the competitiveness of both quality and price of recycled aggregates must be guaranteed. Thus, the price of the recycled aggregates shall remain less than the price of the pure material which was the basis of the sale price assumptions.

Therefore, the tipping fee will not only determine the cost recovery and the successfulness of achieving the return on investment during the course of the contract, but also provides environmental benefits and supports implementing the waste management strategy in terms of waste reduction from the source, and promotes use of recycled material.

5.7 Tipping fee and illegal dumping

Although tipping fee is used as a tool to enforce waste reduction and encourage the reuse and the recycling practices, however, high tipping fees may lead to illegal dumping which causes adverse environmental and economic impact, especially when high tipping fee is charged. Figure 26 shows the number of illegal dumping incidents in Abu Dhabi emirate. The amount of illegal dumping has significantly reduced in Al Ain city, whereas Abu Dhabi city and Western Region still face the challenge of huge illegal waste quantity.

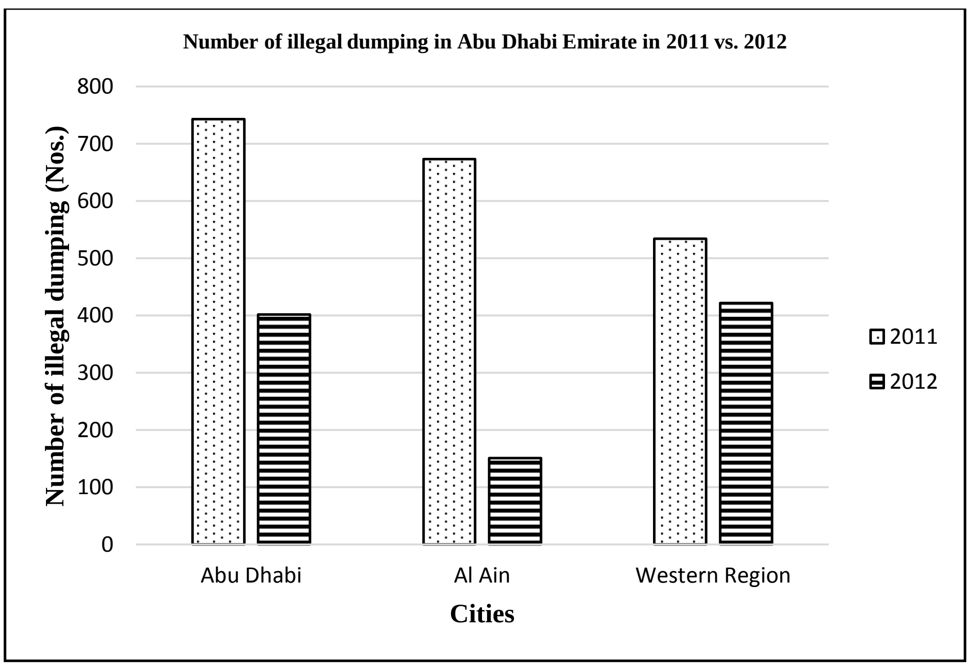

Figure 26: Number of illegal dumping in Abu Dhabi Emirate in 2011 versus 2012

To overcome the illegal dumping, competent authorities shall develop sufficient enforcement system including deterrent penalties for non-compliance incidents. The enforcement system will reduce the amount of the illegal dumping which will subsequently result in to increase of C&D waste sent to the C&D waste treatment plant.

Lastly, in order to avoid sending C&D waste to the dumpsites as mixed waste, dumpsites fees shall be imposed on the waste generators which not comply with waste segregation at source. The dumpsites fees shall set at a higher amount of that of applied at the C&D waste treatment plant.

The dumpsites fee will assure higher amount of waste diversion from landfills, and the illegal dumping penalties will assure higher amount of waste received at the C&D waste treatment plant.

Chapter 6 Conclusions and Recommendations

6.1 Recommendation

Legislative Orders: The competent authority could issue legislative orders making it compulsory for all demolition projects to obtain NOC certificate from the Center of Waste Management – Abu Dhabi. The demolition contractor will need to submit a consultant report identifying the estimated amount of recyclable C&D waste produced at site, in addition to an undertaking to abide by the regulations regarding C&D waste.

Similar mechanism could apply to all new construction projects. The submitted report should include a waste reduction plan in addition to undertaking by the builders / developers to dispose their construction waste at the crushing plant.

The builders should obtain NOC certificate from the Center of Waste Management – Abu Dhabi in order to receive the competition certificates of the project. The NOC certificate will be issued based on the approval of both waste minimization at site and the C&D waste disposal at the C&D waste treatment plant.

Moreover, it is recommended that relevant legislative orders to be issued by competent authorities to penalize the non-compliant parties and those who conduct illegal dumping. The penalties with regard to the illegal dumping should be of a high deterrent amount to guarantee disposing the wastes at the designated plants / sites.

In addition, in order to avoid variation in the composition of C&D waste being sent in a mixed form of waste to the dumpsites, legislative orders could be issued for the non-compliant construction / demolition companies with waste segregation at source. On the contrary, companies show commitment to the segregations and reuse of material will gain financial incentives and compensations.

Tipping Fees: The CWM-AD could develop a mechanism and time frame to implement the collection of tipping fee for C&D waste. The tipping fees will be charged by CWM-AD at the crushing plant based on tonnage of waste and issue a weighbridge ticket stating the quantity of waste, unit rate and amount. The suggested amount for the tipping fee at this stage is ten (10) AED/ton.

A higher amount for the tipping fee at the dumpsites to be charged by CWM-AD in order to enforce transferring the C&D waste to the treatment plant. The dumpsites fees will turn the recycling financially competitive with the conventional disposal.

Awareness and Education Programs: CWM-AD could conduct continuous market awareness about the waste reduce, reuse, and recycling benefits in the construction industry. Various incentives could be announced in order to persuade construction companies to abandon the current practices for more sustainable and environmentally safe actions.

Marketing: the recycled aggregates needs to be approved by the Abu Dhabi Quality and Conformity Council (QCC) in order to encourage construction companies using the recycled material in their projects. It is highly recommended to support and encourage the use of recycled material by the General Secretariat of the Executive Council (GSEC) through enforcing the use of recycled material in the government projects. Necessary decree can specify the minimum amount of the recyclable material usage in each of government-funded project. The major departments to use the processed aggregates in their projects are Department of Municipal Affairs (DMA), Department of Transport (DOT), and Etihad Rail (UR).

The above mentioned government departments should specify the recycled material and the processed aggregates in the treatment plant in the bill of quantities of their bids. Specified amount for use of recycled material will be compulsory for their contractors.

The marketing programs may include customizing attraction incentives for the companies achieve usage of certain amount of recycled material in their projects.

6.2 Conclusion

The Center of Waste Management – Abu Dhabi (CWM-AD) being the competent authority in the waste management sector, has initiated environmentally sound projects which deploy advanced solutions toward sustainability.

The waste management strategy is part of greater Abu Dhabi's 2030 vision in which the environmental sustainability is identified among key priority areas that will develop and strengthen the architecture of Abu Dhabi's social, political and economic future. Al Ain C&D waste treatment plant is an example of several environmental projects wherein the government has supported and significantly subsidized.

The study highlights important issues in regards to the financial and environmental objectives of Al Ain C&D waste treatment plant.

This case study provides insights into the cost recovery efficiency of the project and the management of the construction and demolition waste. It was undertaken by identifying the relevant factors, reviewing the feasibility study of the project, analyzing the current situation, and developing a financial model in order to identify optimized scenario for the cost recovery and provide an integrated solution for the management of construction and demolition waste.

The literature review provided helpful guidance in identifying the relevant factors. The considered factors were as following: (1) waste hazards and its' environmental adverse impacts and on the other hand, the potential benefits of managing waste. This includes the environmental, social, and economic benefits. (2) The construction and demolition waste in specific, the sources and composition of C&D waste, the generated quantity of C&D waste, the factors influencing the quantities produced, and the current practices including disposal or treatment of the C&D waste. (3) The strategies and principles of managing waste which focused on reduce, reuse, and recycling. Moreover, the environmental, social, and economic benefits of implementing these principles. (4) The costs involved in recycling projects and the sale of recycled material, relevant laws and legislations, and the environmental impacts of current practices and recommended solutions.

The findings of the study highlighted the negligence of clear cost recovery approach, lack of necessary legislations and financial / managerial solutions. A financial model was developed to identify the likely scenarios based on reasonable assumptions. The model consist of major relevant factors which will determine the revenue and the duration of cost recovery. The identified scenarios elaborated that the current situation will fail in achieving the return on investment during the course of the contract regardless of the adverse environmental and economic impacts of current practices.

The study promoted the tipping fee as a widely implemented tool for recovering the investments in waste management and the enforcement of environmentally sound practices. It provided as well different options in terms of cost recovery duration in addition to a set of integrated solution to better manage the construction and demolition waste.

The study recommendations a number of solutions which collectively will provide an integrated solution for an efficient and cost effective environmental practices. It includes developing legislative orders by the competent authorities which will lead to waste reduction, segregation at source, higher amount of waste diversion from disposal sites, and illegal dumping prevention. The relevant decrees will enhance the quantity of waste to be recycled and enforce the reuse of recycled material, in addition to providing specified penalties for the non-compliance.

More importantly, developing a mechanism and time frame to implement the collection of tipping fee of ten (10) AED/ton at the treatment plant and higher amount for the tipping fee at the dumpsites were recommended.

Finally, the governmental support and encouragement were introduced as marketing solutions, besides the awareness and education programs.

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