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A REVIEW OF SYSTEMATIC APPROACH FOR SUSTAINABLE REDEVELOPMENT OF A CLOSED LANDFILL SITE

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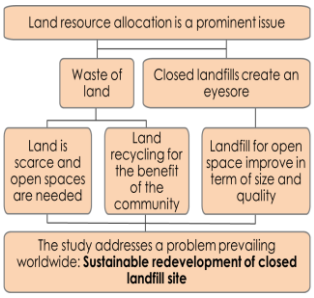
Graphical abstract



Abstract

Landfills are the common method of waste disposal. A closed landfill site can be an eyesore land and cause environmental hazardous impacts on surrounding areas. A sustainable solution for redevelopment of a closed landfill site, returns the land to an attractive and beneficial after-use. This study aim to identify potential sustainable solutions and factors in the redevelopment of closed landfill sites. The paper critically reviews the literature regarding vital understanding of the redevelopment process. The study also analyzed the successful landfill redevelopment projects in a wide range of time and locations to suggest the best end-use option. Additionally, the study offers an approach for integrating the social, economic and environmental benefits through the sustainable redevelopment solution contributing to the universal sustainable development and green built environment.

Keywords: Sustainable development, closed landfill redevelopment, landfill after-use

Abstrak

Tapak pelupusan adalah kaedah yang selalunya digunakan untuk melupuskan sisa pepejal. Tapak pelupusan sisa pepejal yang telah ditutup akan menyebabkan pemandangan yang tidak elok dan memberi kesan bahaya kepada kawasan persekitarannya. Pembangunan semula bekas tapak pelupusan sisa pepejal melalui pembangunan mampan akan mengembalikan daya tarikan dan faedah kawasan tersebut. Oleh itu, kajian ini bertujuan untuk mengenalpasti potensi dan faktor penyelesaian lestari dalam pembangunan semula bekas tapak pelupusan sisa pepejal. Kajian ini akan secara kritis menyorot bahan bertulis mengenai proses pembangunan semula bekas tapak pelupusan sisa pepejal. Ianya juga akan menganalisis penyelesaian terbaik pembangunan semula bekas tapak pelupusan sisa pepejal yang telah berjaya dibangunkan dari pelbagai julat masa dan lokasi. Selain itu, kajian ini juga mengetengahkan faedah hubungan integrasi sosial, ekonomi dan alam sekitar melalui penyelesaian pembangunan semula mapan yang menyumbang kepada pembangunan mapan sejagat dan reka bentuk persekitaran hijau.

Kata kunci: Pembangunan mampan, pembangunan semula bekas tapak pelupusan, pengguna bekas tapak pelupusan sisa pepejal

1.0 INTRODUCTION

Since the industrial revolution, a huge amount of waste has been producing. Thus, there was a need to find a proper method for waste disposal [1]. There are few common methods for waste disposal such as landfilling, incineration and recycling [2]. Landfill being considered as the most common and oldest

method of waste disposal and likely to be first choice in the near future all around the word [3]. Besides the piece of land, to construct a landfill need to spend much money. So the question arise what is the end of a landfill life cycle. This issue is more significant as many of the landfill sites are in or nearby urban areas where a piece of land is scarce and environmental hazardous are serious problems. The solution for this question is to re-use of the closed landfill site [4]. Since a landfill area is considered as a contaminated land, it is vital to have a proper plan to make the procedure of redevelopment successful. Sustainable redevelopment of a closed landfill site is more likely to be accepted by public and hence avoiding of failure [5]. Figure 1 briefly elaborate the importance of this research.

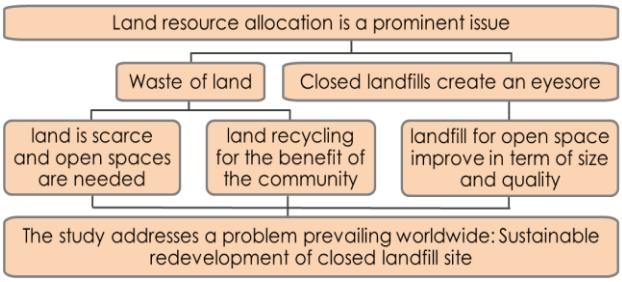


Figure 1 The importance of landfill redevelopment

2.0 METHODOLOGY

To address a systematic approach for sustainable redevelopment of closed landfills, this study has critically done a comprehensive literature investigation among existing papers and other useful resources to achieve this aim. In fact the sections of the paper represent most important issue that should be considered for a sustainable redevelopment of a landfill site. The study also reviewed with a very detailed comparison of some successful landfill redevelopment projects to identify the best possible after-use options which is very important to achieve sustainability.

3.0 LIFE OF LANDFILL

3.1 Landfill Siting and Planning

Policies and community concern make siting of the landfill very difficult [6]. To select a suitable site, three types of aspects need to take into account. First is the rules and regulation; second is the social aspect which include public oppositions and acceptances; and third is the technical aspects that namely can be: topographical; geological; meteorological, and hydrological aspects, as well as traffic pattern [7].

3.2 Landfill Designing

As other land use design, a landfill is also similar to other design procedure. However, there are specific design procedure to be applied for landfill particularly [8]. These considerations namely are:

- Water management includes surface and underground water
- Bottom insulation and linear
- Leachate collection, transmission, treatment and management
- Gas extraction, capturing and management
- Landfill cells
- Final capping method

3.3 Landfill Construction

Landfill construction refers to the construction of incidental and necessary facilities toward development and closure of the landfill [9][10]. These facilities normally include:

- Earth work
- Surface water controls
- Site work
- Ground water controls
- Leachate collection and treatment methods
- Bottom and side liners
- Gas capturing and controls
- Final cover techniques and method

3.4 Landfill Operation

Landfill operation relates to the real waste disposal practices and landfilling activities as well as the operation and maintenance of the aforementioned services and facilities [8].

3.5 Landfill Closure and Post-Closure Care

Landfill closure refers to the completion or ending of the operation [11]. In real life of the landfill, the only main action that ends at closure stage is the transferring and placement of trashes [12]. Other functions of solid waste landfills continue, comprising gas and leachate management, surface water management, erosion controls and environmental monitoring. It is uncertain to define the required length of time to carry the necessary activities for a specific landfill site[13]. Some serious environmental impacts such as gas and leachate can continue for almost 30 years or more. Closure and post-closure care are the most important stage of the redevelopment process because most of the technical issue to reuse the site start in this stage[14].

In the next section of the study, sustainable redevelopment of a closed landfill site is explained.

4.0 SUSTAINABLE REDEVELOPMENT OF A CLOSED LANDFILL SITE

Landfill redevelopment in many cases refers to the technical issue that can be an engineering solution [5]. However applying technical solutions do not guarantee the redevelopment projects to be successful, and the risk of failure still remains. Therefore, to have a beneficial and successful redevelopment project, it is the best to follow the principle of sustainability [15]. A project considers sustainable when the three components of sustainability applied. These components namely are Social consideration, Economic consideration, Environmental consideration [16]. However, these terms may be differed from one project to another accordingly. For instance, in some projects environmental consideration may be more about ecological issue or technical part of the project [17]. The World Commission on Environment and Development defined sustainable development as "development that meets the needs of the present without compromising the ability of the future generations to meet their needs" (WCED, 1987).

In the following sections, each component of sustainable redevelopment of a closed landfill site is explained. However, the focus of this study is on technical (environmental) part of the redevelopment.

4.1 Social Consideration

Social consideration as one of the sustainable redevelopment elements is deal with community acceptance and involvement of landfill redevelopment project. In other words, the social issue is in the administrative area of landfill redevelopment focused on: political and social risk, social benefits, land use [18].

As the essence of landfill is to accept wastes and contaminated materials, people identify a landfill as a place of contamination and danger [19]. Thus, redevelopment of a closed landfill site for community use may be at risk. It would be more significant when the cost and process of landfill redevelopment are higher and more difficult than a non-contaminated piece of land. Based on social perception, the most serious problem to the possible redevelopment of a closed landfill is not the existence of contamination, but the social perception regarding the contamination. Therefore, the selected methods in which the potential risk is interpreted and presented are essential to uplift the level of community confidence or trust in the project [20]. In the eyes of the public, successful landfill site redevelopment is often measured as one of the most significant key factors because the outcomes tolerate and are observable for a longer time compared to operational life of the landfill. Also, most of the engineered facilities and infrastructure which are important in precluding environmental impacts and pollution are underground and are consequently not visible [18]. A successful landfill redevelopment site brings back the site into an interesting and beneficial after-use and ensures that any future redevelopment of closed landfill site can also be redeveloped to an equally high standard. As a result of that it will promote public trust and confidence in the landfilling industry [1].

4.2 Economic Consideration

Economic consideration is in the financial area of landfill redevelopment [4] that focus on:

- Economic benefits
- Financial risk
- Financial incentive
- Redevelopment lifecycle costs

Any projects would financially consider feasible when the analysis of cost-benefit fetches up positive [21]. In other words, financial feasibility means when benefits minus costs ends up positive. There are some items that increase the financial risk of landfill redevelopment such as incomprehension of market, unnecessary and undue transaction charges, non-profitability. Furthermore, financial risks could be originated from a particular condition of a landfill redevelopment project, related with the public opinion toward redevelopment risk, environmental risk, and the acceptance of permission for the approval process and the government or local authority regulations [22]. In term of economic consideration of landfill redevelopment, it is crucial the data and information to be clearly adapted. This will help to identify possible proposal that can lead redevelopment procedure to be financially feasible. It is a way to motivate private and public investors to participate to the project that will ensure the benefits for neighboring communities [10].

4.3 Environmental Consideration

Environmental consideration in landfill redevelopment refers to the technical area. Since the core of the technical area comes from engineering solution it may also call engineering part of landfill redevelopment in some resources [23]. The issues that consider in the technical area include:

- Environmental risk and benefits
- Engineer solution
- Landfill characterization
- Site characterization [5]

Whilst social and economic consideration help the redevelopment process of a landfill to be sustainable, technical area or environmental consideration solely brings back a closed landfill to a useful environment or a cleaned land [24]. This shows the importance of the technical area. Therefore, the main goal of this study is to investigate this section.

From the literature, it is found that there are few terms that may make the understanding of the redevelopment process confusing. Thus, before

proceeding to explain about technical area it is vital to define these terms.

5.0 THE MAIN PROBLEMS IN LANDFILL REDEVELOPMENT PROCESS

5.1 Landfill Gas

Landfill gas is generated from decomposition of biodegradable waste. Methane (50-60%) and carbon dioxide (40-50%) besides other organic gasses and vapors are major constituents in MSW landfill [25]. Volume of gas produced by landfill depends upon numerous factors such as the nature of waste material, the moisture content, waste congestion, pH and chemical properties of waste. The major part of landfill gas is produced during the first ten years. Since the landfill gas may cause some severe problems, the threat of landfill gas has not to be overlooked in the redevelopment process. The landfill gas is potentially inflammable, therefore it would be saturated and may lead to an explosion in the closed spaces [26]. Moreover, if the people expose to the landfill emission for a period in such closed spaces, it may have detrimental effect on their health. In addition, existence of landfill gas into root zone of the vegetation can damage the plants. Production of the landfill gas may impact on the entire site surface and leads to plants dieback. Finally, the odor derived from the methane gas could be the chief reason the public to avoid living close to this area or use the ex-landfill site. Cracks or holes in a landfill caps in addition to problem in gas capturing system are two predominant reasons of gas discharge [18].

5.2 Leachate

It refers to any liquid formation from waste disposal that seepage from or remain within a landfill [27]. The quantity of leachate depends on the amount of precipitation, surface water that penetrate into the landfill, the liquid portion of waste, and groundwater impact. There is some toxic impact from leachate. Waterlogging and anaerobic soil conditions are other problems of leachate that may cause dieback of plants. Leachate negatively impacts on ground and surface water and effect the water quality [28]. So leachate can be a source of contamination and danger for human and wildlife especially if the landfill site is located near a wetland or other type of water bodies. Leachate can escape from cracks and hole in capping the layer the same gas, the edge of the landfill, problem in landfill liner, and when it is in a high level causing from penetrating water [29].

5.3 Deferential Settlement

It also called subsidence and occur because of biochemical and physical process of waste decomposition procedure. The final level and contours of the top surface are imperative in landfill redevelopment [11]. In order to succeed the required contours, it is necessary to predict the amount of the settlement that will occur. The rate and degree of settlement occurring at a landfill will always be site-specific and will be influenced by the site conditions, landfill practices, types of waste deposited, and the effects of the mechanical and biochemical processes. Settlement values of between 10 and 25% of the depth of the landfill can be expected for municipal waste landfills [30]. The highest rates of settlement will occur within the first five years with the rates gradually slowing down over time until the waste eventually stabilizes. Differential settlement can create other issues in addition to foundation problems. When settlement causes great stresses in structures or pipelines, underground infrastructures may be affected. This can lead to their failure or malfunction. For example, deferential settlement caused a gravity sewer system to stream rearward [31].

6.0 AFTER-USE REDEVELOPMENT OPTIONS

Selecting a proper after-use for a closed landfill is vital to ensure successful redevelopment will be achieved. To select a redevelopment option, there is a need to consider existing conditions of the site and then define the choice of after-uses [32]. Additional works to settle existing issues of landfill may be required.

6.1 Factors Affecting the Choice of After-Use Option

Likewise other development project, landfill redevelopment requires general consideration in term of inventory and analysis such as climate, landfill client and ownership's (public and private sector) opinion, site geometry, local demand, local recourses, land use zoning, financial conditions [24]. However, as landfill is a specific environment with unique conditions there are also other factors that associate exclusively with landfills. Most important factors in determining the choice of after-use are landfill site characteristics, landfill's environmental impacts and control system, meeting regulation and criteria requirements and consulting with relevant parties, and community opinion and acceptance [33]. The paper discusses these factors below.

6.1.1 Landfill Site Characteristics

Numerous characteristics of the site, as well as the character of the surrounding environment, are significant factors in defining the choice of after-use for the redevelopment of the landfill. These include three main categories [34]. First category is about the physical characteristic of the site and its surrounding areas such as [35]:

- Landform

- Topography
- Condition of surrounding areas
- Existing inside and outside landscape
- Hydrology and drainage and run-off pattern
- Geology and ecology of the site
- Soil quality and availability of soil based on the choice of redevelopment option

Second category refers to type of the waste. For instance, sites which accept mostly inert waste like construction material is capable to have a broad range of after-use while site that receive biodegradable waste like food material will have lesser options [29]. The third category is about site planning and it refers to:

- Size, location and access of the site
- Neighborhood areas
- Land use planning
- Archeology of the site
- History and historical features of the site.

6.1.2 Landfill's Environmental Impacts and Control System

A long-term monitoring, maintenance, and management need to control landfill environmental impacts and pollutions. So this control system include [36]:

- Gas management system
- Leachate management system
- Landfill cover and capping
- Fixing of settlement and slop stability
- Surface and ground water management

The above mention factors affect the choice of after-use [34]. It should be noted that among these pollution controls and environment impacts management, landfill gas (LFG) has the greatest influence on after-use option.

6.1.3 Consulting with Relevant Parties and Meeting Standard Regulation

As landfills are contaminated lands that can spread disease, odor and many other issues, there are certain criteria and regulation prepared by government and local authorities. It is vital the choice of after-use meet those standards and address the concerns.

6.1.4 Community Opinion and Acceptance

Complexity and cost of landfill redevelopment process as a specific contaminated land is much higher than a cleaned land. Therefore, it is always a concern whether the choice of after-use will be accepted by public or not. It is completely risky not to consider public preferences before selecting after-use option; because people has a negative thought to landfills in mind [20].

6.2 After-Use Options

The choice of after-use regardless of the issues of redevelopment and future land use can be in four categories. These are open space, agricultural land use, woodland and hard end use. Each after-use option is explained.

6.2.1 Open Space

Open space is most widely recommended option for landfill redevelopment. Because it is the most flexible option that can be used for many sites regardless of many factors that constrain the redevelopment procedure [37]. In other words, by returning landfills into open spaces the risk of failure will decrease. That is why open space is enforced by governments to be the final land use option in many countries [5]. Open space can be divided into two major groups active and passive. Active open space includes: formal sport field and Golf practice range.

Passive recreational area include a wide range of amenities [38] such as: informal sport fields, nature conservation, civic parks, camping areas, playgrounds, walking and jogging track, pet exercise zone [39].

6.2.2 Agricultural Land Use

The examples of this after-use option are grassland for silage or hay, grazing, and crops like grains. The most constraints of this option include the size of the site (since it does not worth to consider small size for this option), gas management system and quality of top soil [32]. However, agricultural land use is most easily alternative for redevelopment of the landfill and may require minimal maintenance works [40].

6.2.3 Woodland

Proper woodland establishment and tree planting on landfill can integrate the site with the adjusting areas, enhance species diversity and wildlife habitat, improve local landscapes, give an opportunity for recreation and use for economic peruse if the site is large enough [41]. The factors that should be aware for this option is:

- Capping system
- Depth of top soil
- Tree root growing (as tree root can damage capping layers and some of infrastructures)
- Expected rate of deferential settlement

6.2.4 Hard End-Use

The two major categories for this after-use option are residential and commercial development [24]. Residential development includes conventional housing, mobile home parks, and apartments and commercial development may be vehicle parking lots, material storing areas, drive-in theaters, and light weight metal buildings. Landfills, in general, are not

suitable for hard end-use forms of development because of the potential hazards and serious problems unless remedial treatment that expensive and complicated to implement done before construction [21]. Some critical factors that must seriously take into account prior to defining hard end-use option are:

- Safety and health of construction labors
- Explosive and flammable gases
- Toxic gases such as CO2 and H2S
- Corrosive materials
- Settlement and instability

6.2.5 Energy Generation

Demand for renewable energy is increasing all around the world and it creates a challenge to find a suitable land to establish such structure such as solar panel and wind turbines [24]. Therefor a closed landfill site could be potential land for solar and wind energy harvesting as landfill is often developed for passive uses such as open spaces. Another source for generating in landfill site is gas known as LFG. Since landfill gas has been commonly captured for energy and is in practice for many years [42], this research has not focus on this matter. Besides, LFG use, the placement of wind turbines or solar panels at a landfill site represents another potential renewable energy opportunity. The generation of energy at landfill can provide some benefits to the site and the community, including offset of part or all of the electricity required for the site, compensation of non-renewable energy resources, and providing further motivation for increased LFG collection, which could have significantly environmental benefits such as decreasing of potential nuisance emissions as well as greenhouse gas emission reductions [43].

7.0 BEST AFTER-USE OPTION FOR LANDFILL REDEVELOPMENT

It is always a critical question that what could be a best choice for sustainable redevelopment of a closed landfill site. It is arguably difficult to answer this question due to many factors that can influence on decision-making process. In a broader view these factors can be in two categories. First category is related with inherent of the landfill site characters and affecting factors that already explained in section 6.1 Second category is associate with demand and needs of the community where a closed landfill located. For instance, as mentioned in sub-section 6.2.1 open space reduce the risk of failure and it is nowadays as one of the important land-use in urban development. Hard-end use, as another example, usually has a higher demand due to market economy.

As the matter of fact, to address this issue an appropriate solution could be to study about other landfill redevelopment projects to find out the positive and negative points of them and apply the experiences of what others has so far done. For this purpose this research has comprehensively review papers and other sources to find some of the most successful project all around the world for a better understanding of after-use option. See table 1.

8.0 RESULT AND DISCUSSION

To analyze what after-use (end-use) option is mostly used, a bar chart is created based on Table 1. It should be note that since some project use for different end-use in different time, a "Multi-functional use" column add for these projects (Please see table 1).

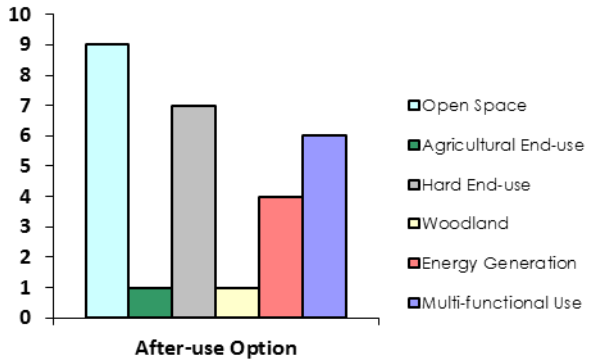


Figure 2 Analysis of after-use options

The analysis of Figure 2 reveals that the most after-use option is open space. The second most is hard end-use and followed by Multi-functional use, energy generation and agricultural/woodland respectively. To interpret our finding we consider the options one by one as bellow.

As there were expected the open space –in variety of functions- is the most after-use option among the selected cases. This is due to many benefits -as already mentioned in sub-section 6.2.1- that, this end-use choice can offer [5].

Surprisingly, the hard end-use option has also applied for landfills redevelopment in a high frequency. However, structures and buildings are not recommended for re-use of landfills. A justification may be because of higher market values that basically can influence on policy makers' decisions to accept such proposals [43]. Nevertheless, a deeper investigation of those projects manifests three useful lessons from these kind of redevelopment projects. The first lesson is that, such successful projects has been done in developed countries with a higher level of technology, standards and caring of human health. It means that an accurate plan and careful construction methods as well as monitoring program have been implemented to avoid of failure and environmental hazardous. Second lesson is about the time of redevelopment and landfills'

characters. As explained earlier environmental impacts of landfills reduce in certain time after closure. Hence, there would be certain stages that landfill sites have less environmental issues and could be acceptable for construction matters. The type of waste as one of the significant factors of landfill character also play an important role on proposing hard end-use option. On the other words, depends on type of waste buried in a landfill proposing a hard end-use might be with less challenges like construction waste. The third noticeable lesson is that, as the time has come to recent the use of hard end-use became less. This could be due to better understanding of landfill lifecycle and do and don'ts of such derelict lands' redevelopment.

Table 1 examples of successful landfill redevelopment

Year of Development or Completion	Location	Project Name	After-Use Option
1960	Liverpool	Childwall Woods	woodland
1976	Florida	Cross State Site	Public Park
1981	Fukuoka (Japan)	The Former Hachida Landfill)	Since 1981: Civic Park ➡ Primary School ➡ Sports Arena ➡ Community Hall
1991	Berkeley, California	Cesar Chavez Park	Public Park
1992	Fukuoka (Japan)	Imazu Sport Park (The Former Imazu Landfill)	Since 1992: Civic Park ➡ Urban Farm ➡ Sewage Treatment Facility ➡ Welfare School ➡ Community Hall
1992	Florida Keys	Key Largo Landfill Facility	Planting And Growth Promotion Of The Shrub/Tree
1993	California.	Colma Landfill	Home Depot (Commercial Business)
1993	Palm Beach County, Florida	Dyer Boulevard Landfill	Multi-Facetted Sports And Recreational Facility
1994	Seminole County, Florida.	Sanlando Landfill Facility	Sanlando Softball Complex
1996	Kaohsiung (Taiwan, R.O.C.)	Shichinpu Landfill	Since 1996: Civic Park ➡ Art Gallery ➡ Sports Arena ➡ Power Plant ➡ Sites For Temporal Waste Storage
1997	Massachusetts.	Millennium Park	Public Park
1998	Wanaque, NJ	Passaic County,	Community College
1999	Elizabeth, NJ, USA	Jersey Gardens Mall	Mall, Hotels, Commercial, Ferry Service
2000	Montebello, California	Montebello Town Square	Shopping Plaza
2002	North Wildwood, NJ	Seaboard Point Resort	Residential Condominiums
2003	Atlantic City	Borgata Casino	Hotel, Casino & Spa
2004	Taipei (Taiwan, R.O.C.)	The Former Fudeken Landfill	Since 2004: Civic Park ➡ Power Plant ➡ Sites For Temporal Waste Storage
2004	Tel Aviv	Hiryia Landfill	Public Green Space
2005	Sapporo (Japan)	Moerenuma Landfill	Since 2005: Civic Park ➡ Art Gallery ➡ Winter Sports Facility ➡ Community Hall
2006	Atlanta, Georgia	Lakeside Marketplace Landfill	Regional Mall (Shopping Center)
2006	New Jersey	Encap Golf Holdings, LLC	Golf Course, Commercial Development, And Residential Areas
2006	Bayonne, NJ	Bayonne Golf Course	Golf Course
2012	Los Alamos County	Los Alamos County Landfill	Solar Panel
2012	Algiers City. Algiers	Oued Smar Landfil	Recreation Park With Green Space
2012	Florida		Solar Energy Harvesting
2012	Miami, Florida		Solar Energy Harvesting
2012	Tampa, Florida		Solar Energy Harvesting

The term multi-functional after-use applies for those projects that are redeveloped with diverse end-uses such as golf course and residential areas or applies for other projects that have different after-use option in different stages of landfill sites. Both solution are a good idea for landfill redevelopment because following reasons. In first case, it should be noted that not entire area of landfills always occupied by trash. Meaning that, a landfill site normally comprise trash zones and non-trash zone or original ground of the site. Therefore it gives opportunities to use non-disturbed area of the site for certain insensitive options. In second case, mentioned previously, landfill characters and its environmental impacts change gradually as the landfill getting old. In addition we can consider a landfill lifecycle in certain stages. Thus different after-use option in different stage of landfill lifecycle can be proposed.

Regarding energy generation choice, the analysis of Table 1 and Figure 1 shows that this option for sustainable redevelopment of closed landfills is getting more popular. This is because of the demand of renewable energy in many countries as explained in section 6.2.5. Finding lands for allocating of solar panels or wind turbines is a challenge. That is why considering landfill sites would be an appropriate solution. For example, it is estimated that there are about 100,000 closed landfill sites in the United States only [44]. Another advantage of this after-use refers to it passive usage as it is recommended not to apply active options for re-use of landfills in many circumstances.

Agricultural land-use and woodland are less used in the projects we studied. There are two main reasons that can justify this. First, the study look at the successful projects. Basically agricultural purpose and woodland recommend when landfill owners do not want to spend money or effort on the landfill. So, this kind of redeveloped landfills has not been in scope of this research [41]. The second reason is associated with landfill characters in term of size, landform and health issues. Many of landfills are not large and leveled enough to be proposed for such end-use options. On the other hand danger of contamination and poisonous soil do not encourage people to go for agricultural land-use. Last but not least, planting trees on top of a landfill have to be with so much caution as trees' root can damage capping system and landfill gas is also harmful for trees to growth successfully [40].

8.1 Beginning and Phased Development

An important question in landfill redevelopment process is when the project should start. As already mentioned, the redevelopment project should begin as early as possible. It is important to know that when the redevelopment process start in earlier stage many of closure and post-closure activities include maintenance, aftercare and selecting after-use will carry out accordingly. As a result the cost and complexity of redevelopment will decrease while the feasibility of project increase [45]. Landfill develops on phased approaches and should be redeveloped progressively over its entire lifetime. The phasing of the redevelopment should be considered when selecting a proper after-use. That is why, it is the best to consider final landfill end-use as a main objective of the redevelopment in the earliest stage of site development. Thus, the work and consideration of each landfill stage include siting and planning, designing, construction, operation, and closure, and post-closure care will conduct with this intended future land use [5].

9.0 CONCLUSION

In summary, a landfill redevelopment process considers sustainable when social, economic and environmental components will be applied. This is critical to ensure that the risk of failure decrease as landfill is a particular piece of contaminated land with a negative impact on public opinion. The paper briefly highlighted the necessary attentions for successfulness of the project with more focus on the environmental issue as the most effective parts of the redevelopment project. A matrix table of successful project and its analysis carried out for a better understanding of compatible after-use option for landfill redevelopment. The framework of this study that obtain from a comprehensive literature review can be used as a systematic approach and concise structure of closed landfill redevelopment for all stakeholders involved in the landfill industry.

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