

# A Study on the Evaluation Indicators of the Regeneration of Brownfields in Taiwan - A Case Study of Formosa Chemicals & Fibre Corporation (Changhua Plant)

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**Abstract.** Industries in Taiwan have developed for up to 60 years, but many industrial zones, pieces of industrial land or other related resources have gradually shown signs of decline, and manufacturers and factories have even gone bankrupt or transferred their production sites to other countries, which has caused the redundancy and neglect of the industrial land. Most of these sites were originally located in the urban fringe, but are, due to the cities' expansion and alteration, now gradually adjacent to them. Civilians and environmental groups are considerably concerned about the impact of "brownfield" on their sphere of life. Accordingly, the study summarizes the relevant research and data regarding brownfield, and constructs the evaluation indicators of the regeneration of brownfields through empirical research of FORMOSA CHEMICALS & FIBRE CORPORATION. The purpose of the study is to offer indicators, in multiple aspects, for assessment and inspection, in hope of being a reference to the relevant policy and studies of the assessment for activation and regeneration of brownfields, so that the brownfields in cities can play its due value.

## 1. Introduction

While Taiwan has experienced decades of high economic growth and urban development up to the present time, the industry structure has changed. Nevertheless, the land has been continuously developed in the pursuit of economic progress, causing urban growth to be out of control. Constant development toward suburban area also results in the decline of city central parts[1]. Notably, the rapid growth of Taiwanese industries in the 1950s to 1980 has led to the construction of numerous pieces of land for industrial purpose. According to the statistics in 2012 by Bureau of Industry, Ministry of Economic Affairs, the current land area of urban planning industrial zones is 21,999.23 hectares, and that of non-urban D-class construction land is 22,284.94 hectares. However, the industries in Taiwan has continually developed to the present time, many of which have gradually declined and transferred their production sites from Taiwan to other countries, as the times and industrial structure change. In addition, policies have been focused on economic development in the past, neglecting the importance of environmental protection, for which industrial development and its alteration have even caused land pollution, or conditions such as redundancy and neglect or abandonment. Nonetheless, opinions and thoughts about development of brownfield are still not be concerned or adopted in Taiwan. Brownfield development can only apply the laws and approaches relevant to urban planning and urban renewal, but relevant pollution remediation falls within the responsibility of environmental protection authori-



ties. Moreover, other bottlenecks exist, to the implementation of the regeneration of brownfield, such as lack of large amounts of money and technology, the prolonged process, etc. For this reason, the study has reviewed relevant domestic and foreign literatures and related cases, and summarized the environmental, social and economic problems of industrial zones in Taiwan, attempting to apply the thought of brownfield regeneration to the cases in Taiwan. The purpose of this study is to construct assessment indicators for regeneration of brownfield, through the empirical case study on Changhua Plant of FORMOSA CHEMICALS & FIBRE CORPORATION (hereinafter referred to as FCFC plant), which has reviewed the current condition of the brownfield in that plant, hoping to offer a new thinking direction for regeneration of brownfield, in consideration of environmental protection, socio-economic factors, and sustainable development.

## 2. Literature review

### 2.1 *Formation and definition of brownfield*

Most brownfields are the deserted fields after industrial economic activities. They began to appear in the first stage of industrialization, and in Europe, they emerged in the United Kingdom in 1800-1914, in Germany in 1870-1940, in most of Eastern Europe and Southern Europe In 1900-1970[2], but in the United States in the period between 1877 and 1980. Along with the general urban development trend, brownfields are involved in the urban sprawl, and are also the result of the influence of urban economy and culture. Namely, brownfields are the irreversible consequence of the land use for extensive industrial development in the early stage. The problem of early brownfields did not attract much attention from all sectors of the community. In recent years, with the awareness of environmental protection enhanced, the problem of brownfield is increasingly noticed. The government and regeneration of brownfields can not only provide local authorities with financial income and employment opportunities, but also comprehensively promote the development of society, economy, and environmental health, leading to win-win benefits in the economic and environmental aspects[3].

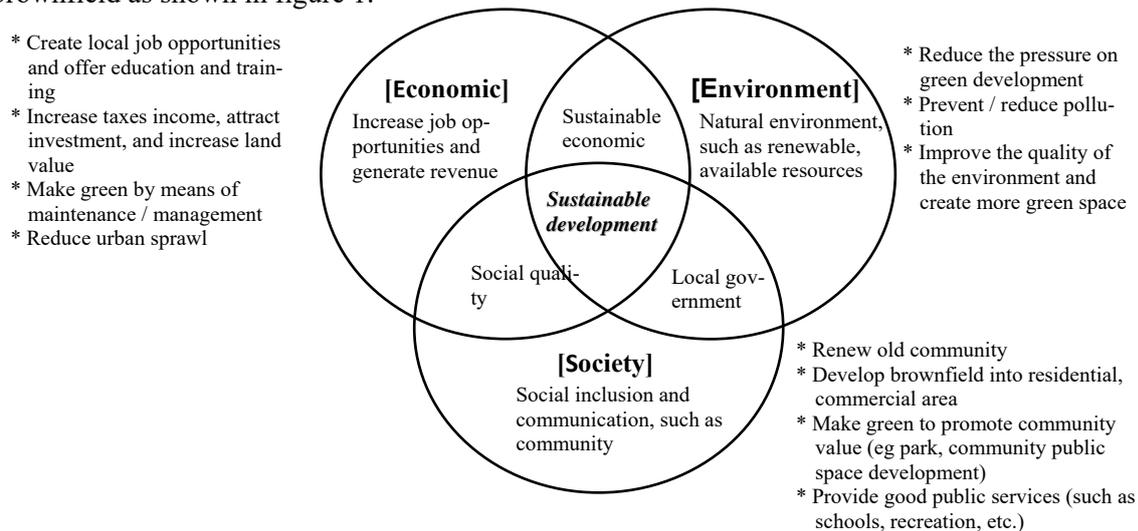
However, the formation of brownfields is often accompanied by changes in urban structure, industrial restructuring, environmental pollution or other factors. Moreover, urban development is even severely affected by the redundancy and neglect due to the outward shift of industries, and low or improper use and under-utilization of brownfield. A number of pollution incidents have broken out and pollution sites have emerged in Taiwan over the past few decades, along with the process of the active development of secondary and tertiary industries. Considering the nature of industrial development in Taiwan and the characteristics of Taiwanese brownfields, the most significant discrepancies between Taiwan and foreign brownfields are their scopes and locations. An entire metropolis is likely to be regarded as a potential foreign brownfield site, but in terms of scale[4], a Taiwanese brownfield is usually hidden in an individual factory or on an idle piece of land, which is situated in the fringe of urban planning zones.

Therefore, according to the above analysis, brownfields are the deserted land and are transformed into dilapidated sites, after the industrial economic activities that utilized them, and they may be associated with pollution, waste, redundancy and neglect, low use of land, or other issues. Moreover, the term "brownfield" is profoundly discussed and explored in Germany, European Union, China and other countries, while in Taiwan, in-depth discussion or research is not common, but is only in the form of a certain initial concept or an exploration.

### 2.2 *Regeneration of brownfield*

The emergence of brownfield not only results in the shattering urban space, and the disappearance of urban functions, but also wastes the resources of urban development, enhances crime rates, and causes economic depression, environmental pollution or other problems. Therefore, the development of brownfield shall be considered to be a sustainable development concept, and its goals are to mend the developed space and integrate functions in urban areas, to improve the urban public facilities and enhance disaster prevention as well as other functions, meanwhile meeting the economic and social needs of current and future generations. "European Urban Environment Brownfield Sustainable Development Plan" demonstrates that the sustainable development of brownfield is an approach to man-

aging and mending land use, and to ensuring that the present and future needs of human beings will be satisfied, within the areas which are environmentally sensitive, economically and socially acceptable where social systems are healthy. Moreover, the benefits of regeneration of brownfield include alleviation for the pressure of land use, intensive and economical use of land, stimulation on economic growth, facilitation in the improvement of the environmental quality and economic development of the whole society, and a positive effect on the ecological environment and human health[5]. For these reasons, this study summarizes the perceptions and opinions of many scholars on the regeneration of brownfield as shown in figure 1.



**Figure 1.** Regeneration of brownfield.

### 3. Research method

This study, through literature review, interviews, case evaluation and analysis, constructs the reviewed regeneration evaluation frameworks of brownfield, and applies Fuzzy Delphi Method for induction on reviewed indicators, and afterward analyzes and probes into the relative weights between the indicators, for the reference of the follow-up study on construction of evaluation indicators for brownfield regeneration. Furthermore, the study, through the in-depth interviews with experts in various relevant fields, explores their opinions and advice on brownfields regeneration policy, and collects the first-hand information from their abundance of knowledge to enhance the depth and breadth of this research.

### 4. Industrial structure changes of FCFC plant and relevant issues

#### 4.1 Changes in industrial structure

FCFC plant set up factory in Changhua, Taiwan in 1965, which led to local economic development and offered abundant employment opportunities. More than 6,000 jobs were created during the period of its greatest prosperity, and that was also important for Taiwan in the economic take-off stage. However, changes in industrial structure and the transfer of production sites cause development bottlenecks of textile industries in Taiwan, especially staple fiber business. It is estimated that sales of related products will not grow within next 50 years, and Vietnam and the countries in Southeast Asia are increasingly developing their textile industries with their cheap labor, so that FCFC plant has lost its competitive advantage. With that disadvantage, the company, after being struggled by environmental groups, eventually shut down its factory in 2016, and is currently planning how to transition.

#### 4.2 Influence of brownfield regeneration on the local area

The location of FCFC plant is located on the borderland between Changhua Old City and the area in the Extended Urban Plan, and in the surrounding area are many settlements and residents. However, according to many relevant reports and the opinions of the environmental groups struggling against

FCFC plant, the factory has a considerable negative impact on the local area, and the affection of air pollution is notably tremendous, so the factory had been constantly requested to relocate. However, it is undeniable that FCFC plant has made a considerable contribution to the local economy. An interviewee, during an in-depth interview, expressed that the development of a city cannot proceed without economic support. Therefore, it is an important issue of how a consensus can be reached among the local residents to resolve the negative conflict, so as to guide the impact of FCFC plant on the local area toward a positive direction.

#### 4.3 Mechanism and approach of brownfield regeneration

Through the analysis of above information and the compilation of the interview data, the domestic operation mechanism of and approach to brownfield regeneration is quite immature. Additionally, in the case that FCFC plant is private properties, those issues, which have not been settled, need considerable discussion and negotiation, such as how brownfield regeneration is operated in the future, how feedback is made or other relevant regeneration mechanism. Accordingly, the major issue on brownfield regeneration is to establish a set of comprehensible and definite mechanism, regulations or others.

#### 4.4 Impact of development of brownfield from the past to the present on urban structure, environment, society and economy

FCFC plant was located in the fringe area of Changhua City in the past, and with the expansion of the city, is now adjacent to the urban area, for which FCFC plant has an impact in multiple respects. In the urban plan on expansion and rezoning of Changhua City, the plant plays an important role in the urban structure of the entire city. In the scope of the renewed old town of Changhua City, FCFC plant is situated in the core area, so the transformation and the regeneration of the factory are bound to have a significant influence on the future development of Changhua City, the local environment, economy and society.

### 5. Construction of brownfield regeneration indicators

The study has developed evaluation indicators for brownfield regeneration, and concludes that the assessment must proceed in consideration of six levels, after studying and researching on the relevant literatures and materials, and after open interviews with experts and scholars in restrictive and objective conditions. The brownfield regeneration indicators description as shown in table 1.

**Table 1.** Brownfield regeneration indicators description

Goal Layer	Layer 2	Description
Brownfield Regeneration evaluation in- dicators	Envi- ronmen- tal	The formation of brownfield is due to the past development of the industry, resulting in the pollution of industrial manufacture procedure to the environment. Accordingly, the evaluation for regeneration must take into account the environmental conditions, any concern regarding pollution, and the extent of contribution to the environment.
	Society	The long-term impact of the brownfield on the local area is tremendous, so the regeneration evaluation should be associated with the rights and interests, development or other social factors concerning the local area, so as to estimate the contribution to the local community.
	Eco- nomic	To assess the contribution of regeneration to the economy, taken into consideration and explored are the benefits of economic development, and the industrial operation model of regeneration, industrial capacity or other economic factors.
	Policy Imple- menta- tion	As brownfield regeneration is realized through the cooperation and specialization in various fields, discussed are the mechanism and operation regulations of policy implementation, and aware of are the laws and regulations, systems, implementation approaches, or other policy-relevant factors concerning brownfield regeneration.

Residence and Life	Taken into consideration are of brownfield regeneration, the influence on residence and life, and the extent of contribution to the quality and the need of life.
Health and Safety	Taken into consideration are the extent of planned contribution to the safety of citizens, and the factors regarding assessment and control of the impact of brownfield regeneration, on citizens' health.

According to the need of this research, questionnaires of the study are distributed mainly to experts, officials and scholars, who have acquired the fundamental and relevant knowledge regarding brownfield and urban re-development. Thirteen questionnaires have been issued and distributed, and ten have been collected, with two invalid ones included. After the arithmetic mean is calculated of the data collected in the study, the research threshold of the study is set as 7.0, which is within the commonly accepted range of 6-8, and the data with  $G^i$  value below 7.0 have been eliminated. Consequently, the recommendations are produced on the suitability and importance of and "indicators for evaluation of brownfield regeneration." as shown in table 2.

**Table 2.** Fuzzy delphi method questionnaires result.

Evaluation Indicators	Ci		Oi		a		Gi	Eliminated
	min	max	min	max	min	max		
Assimilative capacity of environment	6	8	9	10	8	9	8.20	
Improvement extent of environmental quality	5	8	8	10	7	9	7.60	
Investigation, evaluation, and remediation of hazardous substance	5	9	9	10	7	10	8.50	
Ecological protection and rehabilitation planning	4	9	7	10	6	10	9.00	
Growth and decline of biodiversity	3	7	7	9	4	8	6.20	v
Changes to green space	4	7	6	10	5	9	7.00	
Growth and decline of landscape functions in the environment	4	8	6	10	5	9	6.49	v
Employment opportunities for the local populace	3	8	7	10	4	9	6.61	v
Preservation of cultural assets	2	7	6	10	4	10	7.39	
Enhancement of social security and welfare	2	7	6	9	5	8	6.54	v
Increase the area of public facilities	5	7	7	10	7	9	7.50	
Care for underprivileged Groups	1	7	6	9	5	8	7.00	
Community development and identification	4	8	8	10	7	9	8.00	
Promote population dynamics to facilitate local development	2	7	6	9	5	9	8.00	
Diversification in industrial structure	2	7	6	10	5	9	6.58	v
Increased industrial output value	4	7	7	9	6	8	6.50	v
Benefits from promotion of the local economy	5	8	7	10	7	9	7.00	
Price change rate of the surrounding real estate	3	8	6	10	5	9	7.66	
Percentage of site land value added	2	7	5	9	4	9	6.77	v
Unemployment rate and employment rate	4	7	6	10	5	9	6.04	v
The extent to which the government implements the project	5	8	7	10	6	9	6.42	v
Implementation approaches, resource allocation and planning on public - private partnerships	6	8	9	10	8	9	8.70	
Prevention of land speculation	5	8	7	10	6	9	8.32	
Establishment of incentives and feedback system	5	9	9	10	7	9	8.20	
Sound legitimate basis	3	9	7	10	6	10	7.80	
Coordination to land use plan	3	7	6	10	5	10	7.88	
Public safety measures planning	5	7	8	10	7	9	6.95	v

Environmental green area ratio and per capita area of open space in green space	4	7	6	10	6	9	7.35	
Integrity of human-oriented traffic planning	4	8	7	10	6	9	6.59	v
Mobility of public transport	3	8	6	10	5	9	7.34	
Industrial transport line planning	4	7	6	9	5	8	6.90	v
Impact of site use	4	7	6	10	5	9	6.48	v
Operational approaches to management and monitoring of environment	5	9	8	10	7	9	6.32	v
Disaster prevention base and facility planning	4	9	8	10	6	10	8.41	
Escape shelters and evacuation routes planning	4	9	7	10	6	9	8.35	
Green energy use and reuse planning	3	8	6	10	5	9	7.85	
The possibility of healthy lesions	4	8	7	10	5	10	6.83	v
Waste management of industrial development	4	8	6	10	5	9	7.62	

## 6. Conclusion

### 6.1 Impact on Taiwan of brownfield regeneration

This study, by literature analysis and expert interviews, probes into the origin and development of the brownfield in Taiwan, and then further explores the impact of brownfield regeneration on Taiwan. It is concluded that the area is considerably finite of land in Taiwan, but in the industrial development, numerous plants and industrial zones have been built in Taiwan, which indeed, has created an economic miracle for Taiwan in the past, and also laid the current industrial basis of Taiwan. However, with the progress of time and industrial structure changes, many industries are facing the dilemma of elimination or migration, identical to FCFC plant, the case in this study, but this study assumes that the approach to future development is to enhance product value through transformation and redevelopment, adapted to the international trends of environmental protection and low pollution. Nevertheless, in the expansion and alteration of urban structure, the location and regeneration of brownfields affect the development of the cities which the sites are situated in. For instance, the brownfield such as FCFC plant site, the area of which is so immense that it should be taken into consideration in the urban planning process. As the experts proposed that the city should have had a comprehensive strategic plan, in which each single piece of land plays its due role and function. Accordingly, the impact on Taiwan of brownfield regeneration includes not only the improvement of environmental quality and solution to pollution, but also the enhancement of its economic power and its influence on society, through innovative thinking regarding regeneration.

### 6.2 Evaluation indicators for brownfield regeneration in Taiwan

The study has summarized that the fields on brownfield regeneration in Taiwan are very complicated and professional, after the analysis of brownfield regeneration and the expert interviews. Therefore, it is expected that the developed indicators can be applied to the ecological restoration of brownfield and the basis of probe into brownfield regeneration, so that the study may realize its due value, meaning that the regeneration is not just a single land development that becomes a price creation. However, due to the unique characteristics and differences of other brownfields, it is proposed to supplement additionally critical assessment items for a single regeneration case, and to adapt the indicator groups to the distinct nature of the brownfield. The evaluation indicators are summarized as follows table 3.

**Table 3.** Brownfield evaluation indicators summarized.

Aspect	Evaluation Indicators	Explanation
Environmental Aspect	Assimilative capacity of environment	Apply the evaluation items stipulated by Environment Protection Administration (hereinafter referred to as EPA), including soil, geology, topography, surface water and groundwater resources, water quality, air quality, noise, meteorological or other main factors, to as-

		<p>Assess the contribution of brownfield regeneration to environmental carrying capacity, and to monitor its quality and maintain the performance to meet the Standards, so as to achieve the goal of environmental cleaning and protection.</p>
	Investigation, evaluation, and remediation of hazardous substance	<p>Investigate, rectify and monitor contaminants according to the EPA Pollution Control Project, such as wastes, toxic chemicals and radioactive materials, which may be remained by the past industries. Notably, any factors must be described that affect the safety of residence.</p>
	Ecological protection and rehabilitation planning	<p>Assess the contribution of brownfield regeneration to the areas of natural ecosystem, including land ecology, water ecology, natural ecological landscape, habitat and other major areas, so as to achieve the goal of ecological protection and rehabilitation.</p>
	Changes to green space	<p>Assess the contribution of brownfield regeneration to the growth rates of major green space, including the growth rates of tree planting and green area in natural environment.</p>
Society Aspect	Preservation of cultural assets	<p>As the value of historical and cultural assets lies on the base to understand the important meaning of human history, not only should those declared historical resources with cultural assets be preserved, but their potential resources also be described, such as historical sites, historical buildings, cultural assets, industrial landscape, relics, settlement culture, cultural activities, local cultural characteristics, landscape recreation resources and other major areas.</p>
	Increase the area of public facilities	<p>Public facilities are constructions serving the public, including transportation, and facilities for people's livelihood and leisure, education and cultural activities. With the increase in the area of public facilities, the number of served people by the base is accordingly increased.</p>
	Care for underprivileged Groups	<p>Assess the contribution extent of brownfield regeneration to the care of underprivileged groups and blighted communities in the surroundings.</p>
	Community development and identification	<p>As the long-term industrial development on the brownfield has led to the stigma attached to and the sense of disagreement with the locality, assess the contribution extent of brownfield regeneration to the overall improvement of the community and the recognition of the people to the local area.</p>
	Promote population dynamics to facilitate local development	<p>Population dynamics has always been the power source of urban development, the brownfield regeneration facilitates the increase in the local population and causes the regional population inflow, driving the growth of human resources that urban development needs.</p>
Economic Aspect	Benefits from promotion of the local economy	<p>Assess the contribution extent of brownfield regeneration to the local industry stability, industry-driven effect, local industrial development and economic interests.</p>
	Price change rate of the surrounding real estate	<p>Assess the contribution extent of brownfield regeneration to the real estate in the peripheral areas.</p>
Policy Implementation Aspect	Implementation approaches, resource allocation and planning on public - private partner-	<p>Assess the coordination extent on operation among the government, citizens, and the third sector, in which approaches are proposed to incentive system, resource allocation, and policy implementation.</p>

	ships	
	Prevention of land speculation	Land speculation is a major issue of urban development dilemma. For the smooth operation of urban functions, prevention of land speculation can curb improper land use, and land prices speculation, facilitating the development of urban functions.
	Establishment of incentives and feedback system	Current urban renewal incentives: building dimension rewards, building dimension transfer, reduction of or exemption from tax and others; feedback means that the actor of land change is responsible for the cost of such alteration, according to the philosophy of internalization of external cost, and that feedback is required from the value-added benefits of such alteration, in accordance with the philosophy of accrualment of land value increments to the public. Feedback contribution items include land, cash equivalents, planned road land, building a planned road, construction of park square, floor area, and others.
	Sound legitimate basis	Brownfield regeneration involves a number of professional fields, and the extent of its complexity is considerably high. To improve the functions, effective management and operation of various competent authorities, it is required to develop sound laws and regulations in relevant fields to promote brownfield regeneration.
	Coordination to land use plan	Land use plan associates with specific codes, regulations, use intensity, and other directions. The optimal use of land requires prevention of the disorder of land development or excessive land use, and reduction of inconsistent or incompatible land use.
Residence and Life Aspect	Environmental green area ratio and per capita area of open space in green space	Parks and green space are not only landscape buffer zones, but also leisure places, which have the effect of reducing the noise, air pollution and high temperature effect. Environmental afforestation is an important approach to the alteration of urban environment and the improvement in the quality of citizens' lives.
	Mobility of public transport	Increasing the mobility of urban mass transport system will accordingly enhance the utilization rate of the mass transit system, strengthen the function of urban transportation and circulation, reduce pollution to the environment and waste to energy, and improve the convenience and safety of transportation, reaching the goal of sustainable development.
	Improvement extent of environmental quality	Assess the percentage of improvement extent to the status of monitoring indicators for the brownfield site, which did not meet the required standard, such as soil quality, water quality, air quality and others.
Health and Safety Aspect	Disaster prevention base and facility planning	Planning of the disaster prevention base can reduce the loss of the disaster, precluding the deprivation of citizens' lives and enhancing the health and safety mechanism of the city.
	Escape shelters and evacuation routes planning	Proper planning and design on escape and evacuation route can, in case of an occurrence of disaster, enhance the efficiency of escape, evacuation, and salvage, and increase the effectiveness of the rescue, to facilitate the urban security mechanism.
	Green energy use and reuse planning	Energy reuse can both reduce the amount of waste disposal, and promote the re-use of resources, reflecting the degree of recognition of the environmental protection and resource use efficiency in an area.
	Waste management of industrial development	The sustainability of brownfield regeneration requires the mechanism to properly handle the various wastes.

## 7. References

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