Resilient Habitats to Regenerative Regions

Ecological Design Approaches for the Anthropocene

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***Abstract*—Decades of energy intensive spatial planning and construction practices fuelled by industrialisation, coupled with barely regulated landuse controls in most parts of the world, has resulted in an unsustainable sprawl of human settlements across the planet. Modern buildings completely disregarded the local climate and context in the wake of mechanisation of building services while post-world war urban agglomerations mostly become structurally dispersed patches of settlements that relied on private automobile for circulation. Recent understanding on the large scale impact of planning policies fostering excessive energy dependance and environmental degradation, resulting in exponential increase in climate related disasters and thereby generating sustained economic loss, has compelled decision makers to develop alternate approaches for designing human habitats. The development of 'Bioregionalism' in 1970s as a renewed ecological perspective has influenced architects and spatial planners in adopting a more holistic and inclusive view on designing efficient strategies for building and managing settlements. 'Resistance' was replaced by 'resilience' in architectural and planning discourses as a sustainable alternative where working with nature and natural processes, rather than against it, became paramount. The whole sustainable development narrative of the 90s and 2000s was found inadequate to reverse the damage done by human activities in the previous decades as the atmospheric carbon concentration reached a colossal 400ppmv by early 2010s, an increase of almost 150% over natural value in 100 years. Anthropogenic changes in geophysiology has to be reversed through regenerative planning, design and management in order to maintain habitable conditions for the (not so) future generations. The paper discusses several design strategies adopted for regenerative built environments using two case studies to take the ongoing scientific discourse on evolving design approaches for the anthropocene further forward. While the 'Garden Terrace House' is a small-scale residential project that is developed as a resilient alternative to the flood and earthquake prone regions of Kerala, the 'Neo-Lusatian Bio-Economy' is a large scale brownfield regeneration project that explores the complex inter-relationships between spatial structure, economy and society and would steer Germany's ambitions to become carbon neutral by 2030. The projects demonstrate how simple, low-tech strategies can be integrated with modern, high-tech solutions to create a balanced and self-evolving model for building regenerative environments.**

***Keywords*—Regenerative regions, resilient habitats, ecological design, bioclimatic design, bioregionalism, regional planning, architecture, urbanism**

I. INTRODUCTION

Human settlements have grown from small clusters of self-made built-units to sprawling expanses of complex infrastructure that require careful planning and execution along the course of known history. The primal invention that fuelled this expansion is often attributed to the discovery of humankind's ability to control fire, the most primitive medium for extracting energy. The rapid growth in infrastructural development after industrialisation was essentially a continuation of our ability to burn fuel, specifically from coal and other energy dense fossil fuels, at a much higher scale.

This non-renewable energy dependent growth model has had devastating effects on the environment in the past century as manifested by the exorbitant rise in atmospheric CO_2 concentrations during that period. Recorded data has shown that atmospheric CO_2 levels have crossed 400ppm in 2013 [1]. A similar spike in other greenhouse gases can also be observed in the same period, along with a steady drop in oxygen levels [2]. The way we plan built environments, therefore, have played a critical role in exacerbating the climate crisis that we are facing today. The shift from a need based building culture to a market based one is no less to blame. It is inevitable to reconsider the way we plan settlements if we are to make a positive impact, in reversing the destruction we have caused to the planet, as early as possible. In order to comprehend the need for such a change in perception, we have to look into the factors that affected the form and growth pattern of human habitats in the past.

II. HUMAN SETTLEMENTS: A BRIEF HISTORY

The human species' transformation from hunter-gatherers to agriculturalists was believed to be the pioneering historical influence that marked the beginning of built settlements. However, a mounting body of evidence have now shown that it was not geo-climatic factors but the changes in human 'psychology and cognition' that resulted in humans being permanent settlers [3]. Several archeologists now argue that the establishment of built settlements, first among the identified ones dating back to around 14000 years, was the actual reason why farming, started around 11500 years back, become the primary livelihood occupation and not the other way round [3]. However, pre-historic settlements were almost always compact and dense, were closer to basic resources like water or fertile land or metal and stone mines and were designed to be defensive against the wild animals and enemy communities alike.

Cedric Price's analogy of the *'City as an Egg'* (1982), rather unintentionally, reveals the factors that affected the nature of urban development over different periods [4]. Price noted that cities built during ancient times resemble the section of a boiled egg, with strong fortifications on the outside (egg white) protecting a dense urban core (egg yolk). This typology can be identified as the *Defensive City*, where the primary factor affecting the settlement's development being protection from enemies, human or wild. Most ancient settlements were developed as defensive colonies since enemy attacks, particularly ground based ones, were frequent and protecting collective assets were crucial in surviving harsh weather conditions.

The second city type in Price's notes consisted of the *Trading City*, which resembled a fried egg [4]. These settlements were early industrial towns and major trade centres developed between 17th and 19th centuries, with a dense urban core, or the Central Business District, surrounded by settlements radiating with progressively lesser densities from the centre. Cities like Amsterdam fit the profile and were developed as major trade centres. In most cases, their location was influenced by the presence of major transportation routes, mostly along a river or a sea, or a specific geographical feature that could provide valuable resources, like an oasis. These settlements were larger and more spread out than before. Their urban forms were greatly influenced by the then new 'merchant capitalist' economic system, a pre-cursor to the modern day capitalism, introduced as a reaction to the discovery of new trade routes to Asia and further due to developments in steam engine powered ships and transportation machinery. Invention of long range weapons , gun-powder and chemical explosives also influenced the growth of spread out cities as fortifications became an obsolete defence while confronted with powerful explosives.

The third and final type by Price consisted of the *Machine City* (or the Industrial city) of the Modern era, which resembled a scrambled egg [4]. These were urban habitats developed during late 19th to mid 20th centuries, the era of the dawn of the automobile. They were urban agglomerations, consisting of structurally dispersed patches of settlements that relied solely on private automobile for circulation. Widespread adaptation of air attacks, presence of powerful nuclear bombs and bio-weapons during the second world war threatened the existence of any sort of dense urban areas into extinction in case of a war. Consequently, compact cities became perceived as more and more unsafe and dispersion became the key for survival. The sprawling fabric of the Machine city was, thus, as much influenced by the changes in war tactics as is by the advancements in long range transportation systems.

The urban type missing in Price's notes was the post-modern city, or the *Techno City.* These were cities built after the onset of Digital Revolution [5], by late 1970s. Newer, complexly formed materials and surfaces began to appear in buildings and settlements started to become extremely techno-centric. Despite the dawn of New Urbanism in the early 80s to promote people friendly planning, techno cities gained popularity due to their new-world appeal on the mass population. Glass became an increasingly common building material across the globe, reducing thermal efficiency of buildings, especially in the tropics. The development of settlements began to be powered by market movements and real estate economics and were barely influenced by the need for shelter and defence. Built spaces became investment opportunities and hence most developments began to be outsourced. This age also marked the rise of large scale developers as controllers of real estate markets.

Post modern cities were, however, not limited to Techno Cities. Unlike past eras of urban development, where a single core factor was deeply influential in the formal and spatial development of built environment, post modern cities were shaped by multiple social, economic and environmental factors. Parallel urban development ideas emerged during this era including Regionalist ideologies like the vernacular revival [6] and ecological design.

III. ECOLOGICAL DESIGN

Human-induced processes have been influencing the changes in the planetary global ecology since the advent of industrial revolution, [7] hence signified by the term 'Anthropocene', proposed to depict the current epoch we are living in. Universal standardisation and fast paced development has left the environment to perish for the sake of economic growth. Recent understanding on the large scale impact of planning policies fostering excessive energy dependance and environmental degradation overlooking the fact that considerable diversity and regional integration aids economic resilience in the long term [8], has created a renewed interest in restoring the ecological loss caused in the previous decades and thereby reinvigorate the economy itself.

By analysing the nature of development of urban form and fabric throughout the history it become clear that traditionally, cities have resisted the 'flux of the landscape'. Ancient cities reflected 'cosmological order than ecological flows' [4] while modern ones prioritised transportation and land parcelling efficiency over persistence and habitability. Both have mostly disturbed the ecological balance than enhancing it. Ecological design tries to create a symbiotic relationship between the built environment and the natural landscape and enable both to function as an interlaced, resilient network. Adaptive planning models were encouraged through 'exploiting endogenously created knowledge as the development base of a region' [8]. This was to ensure better climate resilience and reduce losses owing to environmental disasters, which may compromise long term economic viability.

Unlike modern urbanist views, ecological design principles do not try to dismiss ideas of the past and create a completely new way of approaching design. It relies on understanding the systemic interrelationships inherent in the forms and processes of nature and re-modelling or re-applying it to plan and manage settlements that satisfy today's needs as well. The simple but most effective technique of layering multiple geo-physical data, pioneered by Mcharg, [9] has revolutionised the way planners engage with landscapes in large-scale projects. By adapting Mcharg's technique to a larger realm, multiple ecological, geological, social, cultural and economic factors could now be taken into consideration simultaneously, so much so that it even formed the basis for the development of most modern GIS analysis softwares.

Ecological design, thereby, relies on ecological resilience as it allows a system to absorb changes by maintaining its main features below a given threshold of disturbance, or change towards a different state above such a threshold, unlike engineered resilience that is stable and inflexible [10]. The strength of ecological design lies in its integration of socio-ecological systems that are 'non-linear, self-organising and characterised by uncertainty and discontinuities'. This integration allows planners to leave space for adaptations and gain new knowledge through continuous monitoring and analysis of policies that affect the systems' performance [11].

Ecological design, hence, priorities regenerative design principles based on persistence, consistency and adaptability over sustainable design ideology based on efficiency and effectiveness [12]. It is a process by which planning is conceptualised 'in participation' with nature unlike the sustainable design narrative of planning 'for' the nature [12]. Such a design strategy should be able to not only support diverse ecological, economical, social, cultural, spatial and functional programs but also integrate them through connected networks of physical infrastructure, hydro-geological processes and socio-cultural interactions and interexchanges [13]. Ecological design identifies connectivity as the prime generator of healthy, resilient spatial form [11] and enables different stakeholders to co-evolve by complementing and not compromising on each other's interests.

IV. CASE STUDIES

A. *The Garden Terrace House*

Resilience, in general, is defined as the capability of a system to absorb or adapt or transform in response to external pressures, guaranteeing safety and preserving its basic functions during a crisis [14]. The Garden Terrace House located at Kodakara, Kerala, on the banks of river Kurumali (Fig.1.), a tributary of river Karuvannur, originating in the Western Ghats and flowing west to the Arabia Sea, had to be, therefore, conceptualised as a resilient built system from the earliest stage of design itself, not by choice alone but by compulsion exerted by the peculiar conditions of its context. The site's position on the river's flood plain, with wet and loose soil and risk of occasional flooding, has mandated a resilient structure that can adapt to the varying seasonal conditions and challenges.

The project was conceived immediately after a major flood hit Kerala in 2018. The site for this project has seen flood levels rising upto 2.5 metres above ground level. Considering the flooding risk, the house was designed as a cluster of three floating rectangular volumes supported by a concrete frame structure (Fig.2.). The volumes are connected by a common concrete channel, which forms part of the structural framework, acting as the rainwater collection pond on the surface. The structure, consisting of the RCC foundation, columns and beams, is designed as a 3-dimensional rib that distributes load equally and balancing the building over the loose soil. This allowed to create a shallow, floating foundation instead of going for an expensive set of deep piles to stabilise the structure. The continuous concrete frame also ensures better resilience against earthquakes.

The first step in reducing ecological impact is to build less. Therefore, the total program area for the building, with three bedrooms, 5 bathrooms and a home office has been reduced to a mere 185 sq.m. from the client estimated 300 sq.m. by eliminating unnecessary wall surfaces, combining functions and efficiently stacking custom designed furniture units into compact spaces. The main program is laid out on the first floor level (Fig.3.), which consists of two bedrooms and associated bathrooms, a living room cum library and a kitchen cum dining space, sharing a mere 121.5 sq.m. The ground floor level consists of a guest bed room and bathroom block of 22 sq.m. area and a small utility space. A separate block consisting of an office and its accessory space, having an area of 37 sq.m. and a rather hight plinth of 1 metre for better flood resilience, can be accessed from the ground floor.

The building materials consists of a mix of pre-used components, like country burnt bricks and roof and floor tiles sourced from demolished buildings from the surrounding regions, components like mud, used for external plastering, sourced from the site itself and virgin materials like the GI sections used for roof and joinery frames as well as wood used for joinery shutters. The components were chosen to meet several criteria including the skillset of the locally sourced labour, client budget, local availability of construction equipments and the overall mass of the building.

By adopting various passive design strategies it was possible to maintain a comfortable interior temperature, which was upto 6 degree celsius lower than the ambient air temperature outside, during summer. Some of the strategies taken for ensuring climate comfort included the thick mud plastering, a double layered roof with an air-gap in-between, carefully placed openings allowing ample cross ventilation and retention of existing tree cover providing an additional canopy over the building. However, the building's solar orientation has been compromised in several instances to maximise the beautiful river view form common living spaces. The additional solar heat gain was, therefore, managed by using triple layered, heat resistant blinds over large west facing windows.

All rooms are designed to receive adequate sunlight during day times and large fenestrations reduce the need for air conditioning as well by channelling air through the room. The entire home is designed to be energy neutral, with a standalone 3kW solar system installed to power the house, minimising its reliance on state power grid in case of emergencies, as inconveniences caused by constant power outrages is frequent in the heavily vegetated region.

Fig.1. View of The Garden Terrace House from the bridge across Kurumali river. Design compromises like the large windows facing west affords excellent views of the river but increases solar heat gain.

Fig.2. View of The Garden Terrace House from the entry gate. The simple rectangular volumes with voids on the ground floor acting as water discharge spaces, to combat flooding, are visible.

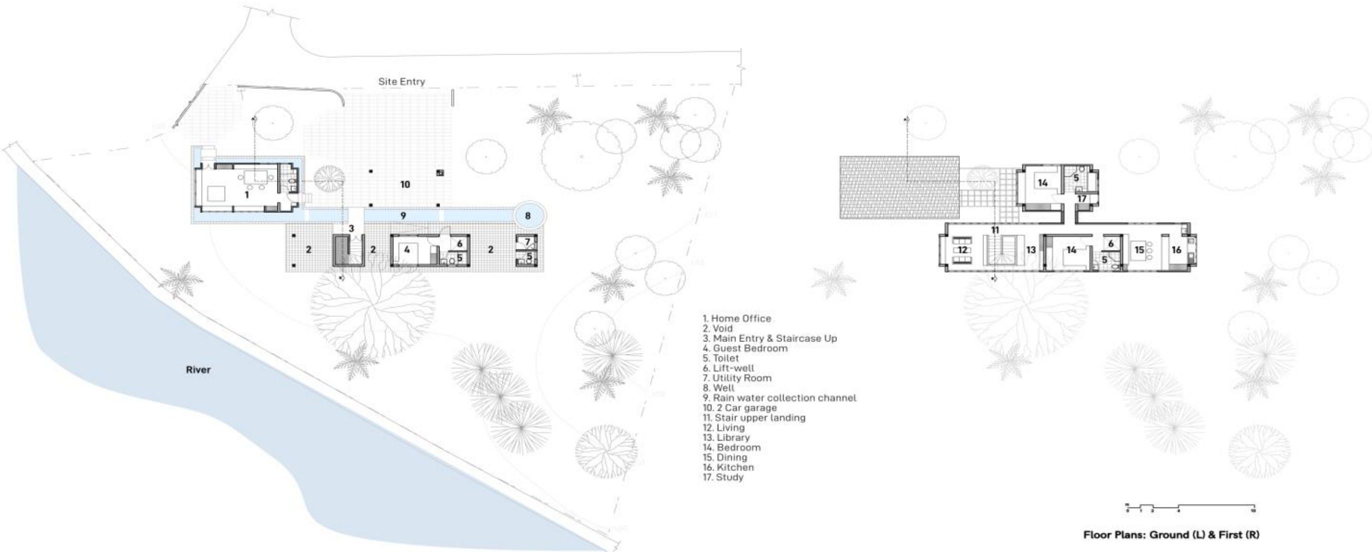

Fig.3. Floor Plans of Garden Terrace House. North facing up.

B. The Neo-Lusatian Bio-Economy

Lusatia is a geo-political region spreading across parts of Germany, Poland, Czech Republic, Slovakia and Ukraine, with a cultural heritage dating back to later Bronze Age. It was once home to a minority population of Lusatian Sorbs, currently limited to Eastern German States of Brandenburg and Saxony and the Polish province of Lubsz [13]. The Lusatian plains, named the Lower Lusatia, spread across the two German states are currently the most important coal based energy production centres in Germany, powering the capital city of Berlin apart from their home states. As Germany is planning to phase out fossil fuel based energy production by 2030, the region, whose economy is tightly knit with coal mining and the associated power plants, faces a critical conundrum. On the one hand the state's decision will allow the region to heal from the ill effects of decades of brutal mining activity (Fig.4.) but on the other hand it will wipe out almost three-fourth of the economy of the region. This project was aimed at managing a smooth transition from a polluting economy to a regenerative economy without affecting the socio-economic balance in the region.

The proposed solution (Fig.5) consisted of a three tier approach to bring back the potentials of once ecologically and culturally rich part of the country. The region's diversity was rooted in its abundance of resources, variety of landscapes and presence of multiple ethnic groups. Lusatia currently retains a small part of its wetland forests, named the Spreewald Biosphere Reserve, and patches of pine forests and hilly meadows. Defunct coal mines were recently converted to large lakes and water reservoirs but still face serious mining related issues like seepage of iron and rare earth minerals from subsurface layers. The Tier One Regional plan consists of documenting all the existing patches of natural landscapes and creating a continuous network of forests, waterbodies and grasslands connecting those patches. This would allow fragmented natural systems to function more holistically and increase the share of ecotones, the fringe areas where two diverse ecosystems meet, where biodiversity is found to be highest [13].

Natural soil healing methods like Phytoremediation by introducing Silviculture were recommended to bring the soil contaminated by mining back to a healthy condition. Controlled afforestation can also provide constant supply of forest produce and store as much as three times more carbon than the atmosphere [15], thereby facilitating the emergence of a new bio-economy in parallel to healing the polluted ecosystem. Several species of trees and plants belonging to families like Brassicaceae, Fabaxeae, Poaceae, etc. that can hyper accumulate soil contaminants including heavy metals were suggested based on previous researches [13]. The networked remedial forests were also instrumental in restoring the lost biodiversity and reinvigorating the tourism industry in the region that was devastated by large scale mining.

The Tier Two Local Area plan involved the regeneration of a mining-field and an associated coal power plant situated in the Jänschwalde area (Fig.6.), close to the city of Cottbus. The proposal was to convert the 21000 hectare coal mine into a renewable energy and bio-produce reserve. The spatial development plan mainly consisted of a "218 hectare Bio-Industrial Hub, a supporting silviculture farm with a total area of 9900 hectares to provide wood and other forest resources to the Hub, a renewable energy park with an installed wind-mill energy generation capacity of 500MW covering ground area of around 45 hectares which shares the landscape with the silviculture farms, 5300 hectares of conserved forests and wetlands for maintaining species reserve and cleansing of surface water and soil and the 5200 hectare lake- which is the only major waterbody to be introduced as per the regional strategy- with public gardens on its banks, public boat houses and recreation facilities" [13].

The waterbody was strategically connected to existing mine-lakes in the locality to form a continuous water surface not only to support boating but also to generate more area for lake-bank Ecotones. The lakes also connect to the existing water channels and rivers through a complex network of anaerobic and aerobic wetland creek system where plants like

Fig.4. Existing View of Jänschwalde power plant and its surrounding landscape. The bare landscape was once a coal mining field.

Azolla and Cattail clean the water impurities to a fair extent [13]. A set of staged plant introduction sequence to effectively carry out this operation, starting from legumes moving up to large trees, was put in place. This strategy also made sure that unskilled and semi-skilled labourers, forming the largest share of the region's workforce, can easily be transformed to work with the new model. The proposed facility was expected to provide at least 10,000 jobs for people with varying skill sets.

The third Tier development consisted of restructuring the existing Jänschwalde Power Plant into a fully functional bio-economy hub. All the re-usable building existing in the power

Fig.5. Proposed View of regenerated Jänschwalde power plant and its surrounding landscape.

plant site was retained and earmarked for adaptive reuse depending on their character. The proposed program included the development of a spatial masterplan of the site and introduction of several core functions like introducing an R&D centre for natural regenerative processes, establishing industries depending on bio-produce as raw materials, developing design and innovation studios and creating a gateway to the new eco-tourism region. The masterplan also incorporated a bio-swale for surface water purification, an exhibition centre for Lusatia's industrial history and heritage and an energy storage facility for retaining excess energy

Fig. 6. Proposed Master Plan for the Janschwalde Power Plant Site to accommodate the bio-economy hub.

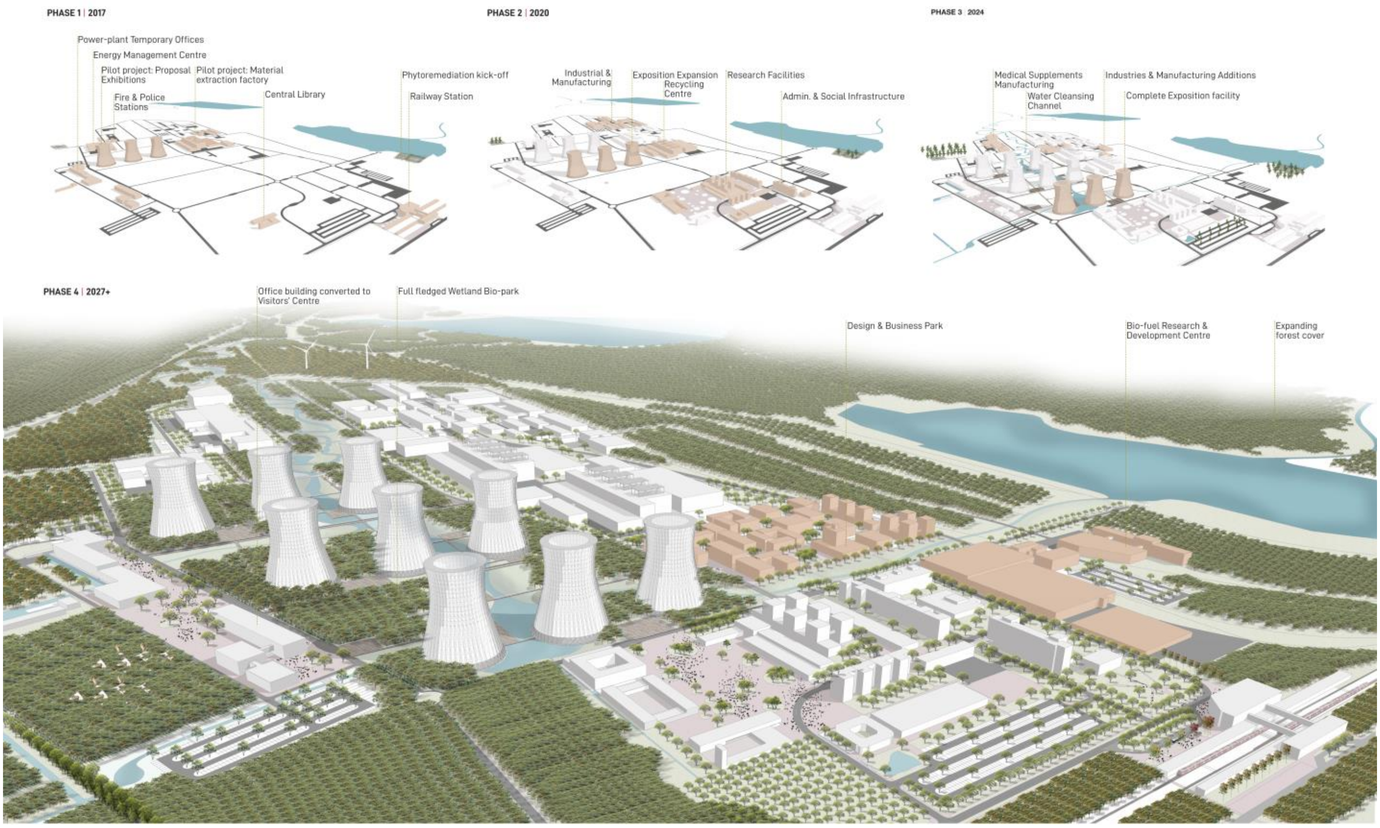

Fig.7. 3D views showing different stages of Masterplan developed as initially proposed.

produced from wind and solar farms associated with the brownfield. A transportation and amenities hub, along with limited number of housing units, were also provided to connect the new 'bio-city' to the existing Cottbus city centre by public transportation and provide daily necessities and services to the occupants respectively [13].

The whole development is divided into four phases (Fig.7.) and an incremental development model was proposed. Each program could be individually altered or replaced at the beginning of a phase depending on the performance of the development activity undertaken in the previous phase. This allowed the project to be flexible and adaptive not only to economic conditions, but also to socio-spatial and temporal conditions, making it mimic the evolution of a biological system based on Darwinian principles. This was incorporated to impart long term persistence and resilience to changing conditions and challenging circumstances in the future. The final result was envisioned as a replacement of the current, scarred landscape to become a new habitat for a species-rich, resilient ecosystem, that supports the regional economy and cultural development in the long term.

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