IN PRAISE OF SPRAWL

GROWING A STABLE URBAN ECOLOGY

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Acknowledgements

Thanks to Jason Slocombe for his guidance and to Peter Fergusion for his time and expertise in mapping.

Abstract

This thesis explores the notion that urban sprawl is the key mechanism for the growth and adaption of developing cities, focusing upon Greater Taipei as a case study. A series of mappings and predictive growth simulations are used to assess how placing a range of urban attractors, with different proximities to existing urban fabric, can encourage different patterns of growth.

"We recognise cities and towns as centers of civilisation, generating economic development and social, cultural, spiritual and scientific advancement. We must take advantage of the opportunities presented by our settlements and preserve their diversity to promote solidarity among all our people." Principle II of the UN Istanbul declaration on Human settlement 1996

In a time where over 50% of the words population lives within urban centers, this paper is concerned with retaining the diversity of cities whilst they undergo rapid expansion.
It is important that we understand the role of different typologies within the sequence of urban development.

Industry provides the means by which a city can manufacture and trade goods and by doing so provides income for the city which allows it to expand and advance its infrastructure. The provision of work by industry acts as an urban attractor, job seekers migrate towards the industrial centers. This migration is embodied as an increase in residential settlement around the attractor and dramatically improves transport infrastructure. Industries have a limited life span though and the industrial manufacture only supports the city through one phase of its development, when the industry becomes obsolete there is a great risk that the supporting urbanity has no other source of 'nutrient' and will decay, as has been seen in Detroit, America. Industry for example can be seen as the pioneering often being placed in topographically suitable locations and encourages secondary typologies to be formed around them.

Educational institutions on the other hand are implemented within established urban fabrics and unlike industry, education continues plays a key role in the development of the city through all stages of its evolution. In Bryan Roberts 'Education, Urbanization, and Social Change' he investigates the correlation between the types of education being sort and the stages of development the countries undergo in Latin America. Roberts finds that the attraction toward private education is greatest in those countries with an established middle class, in the post industrial stages of development as country moves from a manufacturing / exporting based economy towards a trading or cultural based economy. Educational Institutions therefore can be viewed as a tertiary typology, following industrial, wholesale and residential.

In order to grow a stable sprawl, that is flexible to future change, varied typologies should be introduced into the growing sprawl at different phase of growth. With the understanding that 'some people follow jobs and some jobs follow people' we can categorise typologies due to their importance to each phase of growth and devise strategies for growing sprawl that is not dependent upon a single typology of survival.

Contents

Hypothesis

Urban sprawl occurs on the fringe of an established urbanity in zones with high accessibility to urban attractors. In developing countries, such as China, where social structures are rapidly changing as a response to intense industrialisation, new urban constructs are planed around a single attractor, namely the factory. The industrial process has a limited life span and as a result the urbanity that it supports is fragile.

By studying biological systems of attraction and growth that produce stable and integrated ecologies by comparison to the fragile ecologies of mono-programatic urban sprawl, a strategy can be developed through which key locations and typologies can be identified for strategic intervention. In the first section of these thesis I will study the different types of urban growth, using the biological model as an ideal through which the different systems are assessed. Strategic interventions will drive future phases of development and secure a multi-programatic stable ecology.

With advances in analytical technology and the availability of satellite images we have much greater means by which we can assess and understand urban development and future growth. These new techniques are used to identify 'un-healthy' urban zones and assess the effects of interventions within the existing contexts.

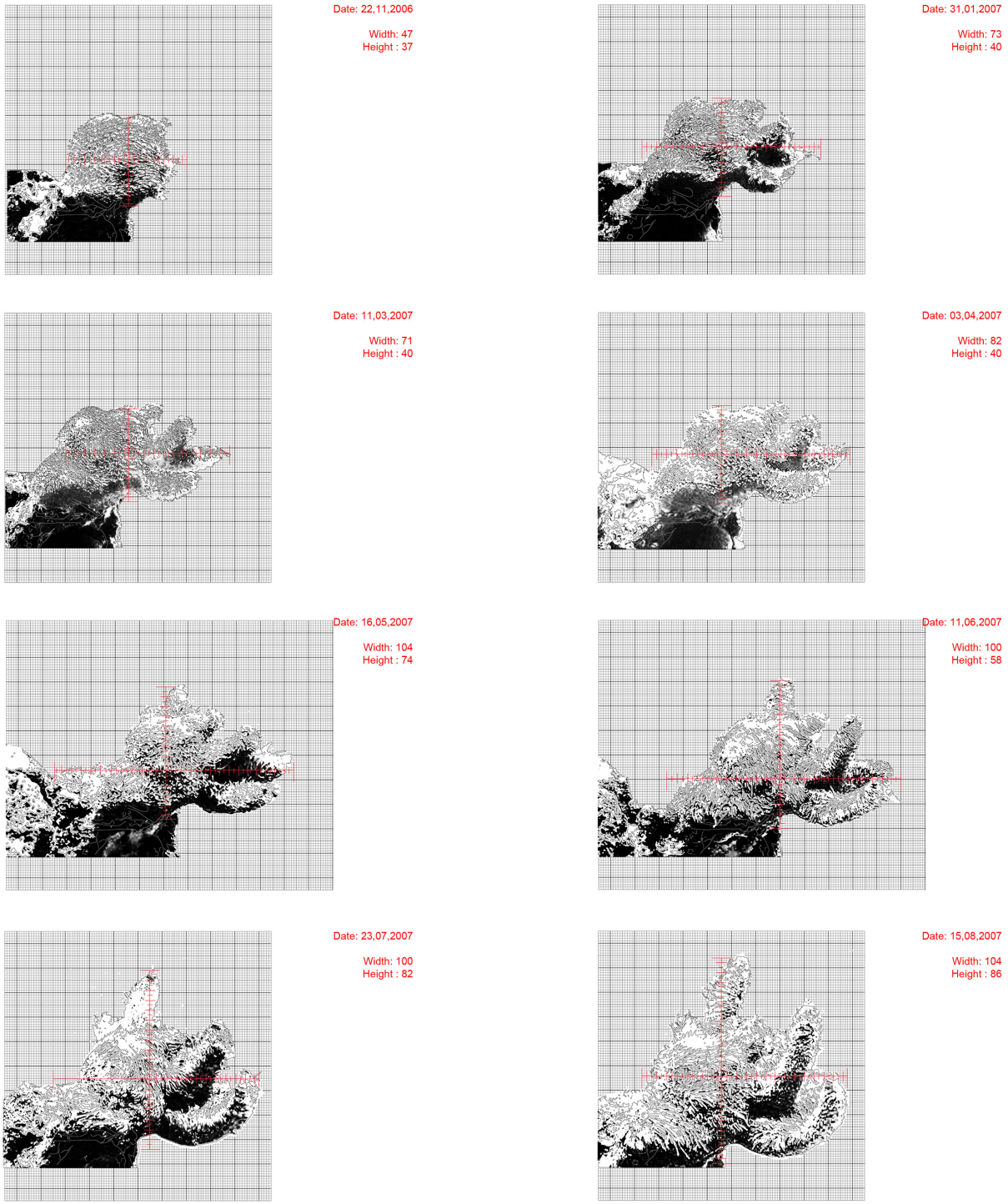


Fig 1:1 Coral Growth Sequence

Natural Evolution and Biological Systems

This thesis is based upon the fundamental belief that architecture is, on both the building and urban scale, a living biome in a constant state of evolution. With this view in mind we can see that a city cannot be designed but is shepherded through its evolution by strategic interventions.

"The role of the architect here, I think, is not so much to design a building or a city as to catalyse them; to act that they may evolve. That is the secret of the great architect." Gordon Pask : foreword for an evolutionary Architecture.

Historically cities formed around topological attractors, most commonly rivers and river deltas. A metabolic relationship with the cities location is established, as the settlement is dependent upon the immediately available resources, if the natural attractors were to dwindle or disappear the cities would be directly effected and die.

As civilisation advanced serval factors allowed settlement to overcome the limitations of the immediate locale, irrigation and intensive farming techniques allow for increased production of food, building advances allowed for the storage of food, and improved transport systems allowed for cities to draw in resources from a far wider area.

Successful settlements act as social attractors drawing people in, as the city becomes saturated new dwellings are established around the periphery of the primary settlement. Over time both the primary dwelling and the secondary peripheral dwelling expand and go through a stage of coalescence merging into a single larger whole. The process of expansion, through diffusion and coalescence, then repeats at a larger scale.

"The aim of evolutionary architecture is to achieve in the built environment the symbiotic behavior and metabolic balance that are characteristics of the natural process." John Frazer : An Evolutionary Architecture

The Evolution of Biological Systems

Through out the history of natural evolution populations of organisms have expanded within their biomes, dependent upon the nutrients available, competition from organisms within the same niche, preditation from higher order organisms. For the most part the development of cities has taken place according to the same set of criteria, usually situated in a location with a great natural resources, removed from other populations requiring similar resources and fortified against any predatory populations.

A comparatively recent change has taken place in the development of the city, the metabolic networks are now global and the competition between cities occupying the same niche has been inverted (competition becomes about the output of goods for trade, rather than for the intake of nutrition). The primary factor influencing city growth is the city's ability to trade, as cities go through the stages of development the nature of the services exported changes. Changes in the requirements of the city and the way that we feed them has created a culture where the city is allowed to rapidly spread as an un-controlled sprawl with little or no relationship to topological restraints or the metabolic capacity of the locale.

Two Cities which typify the problems of this urban sprawl are Los Angeles, California and Taipei the capital of Taiwan, These cities have expanded through the creation of new districts to support the ever expanding population, rather than through the creation of a new settlement on the periphery, which expands and merges with the whole. The issues that arise from "the designed

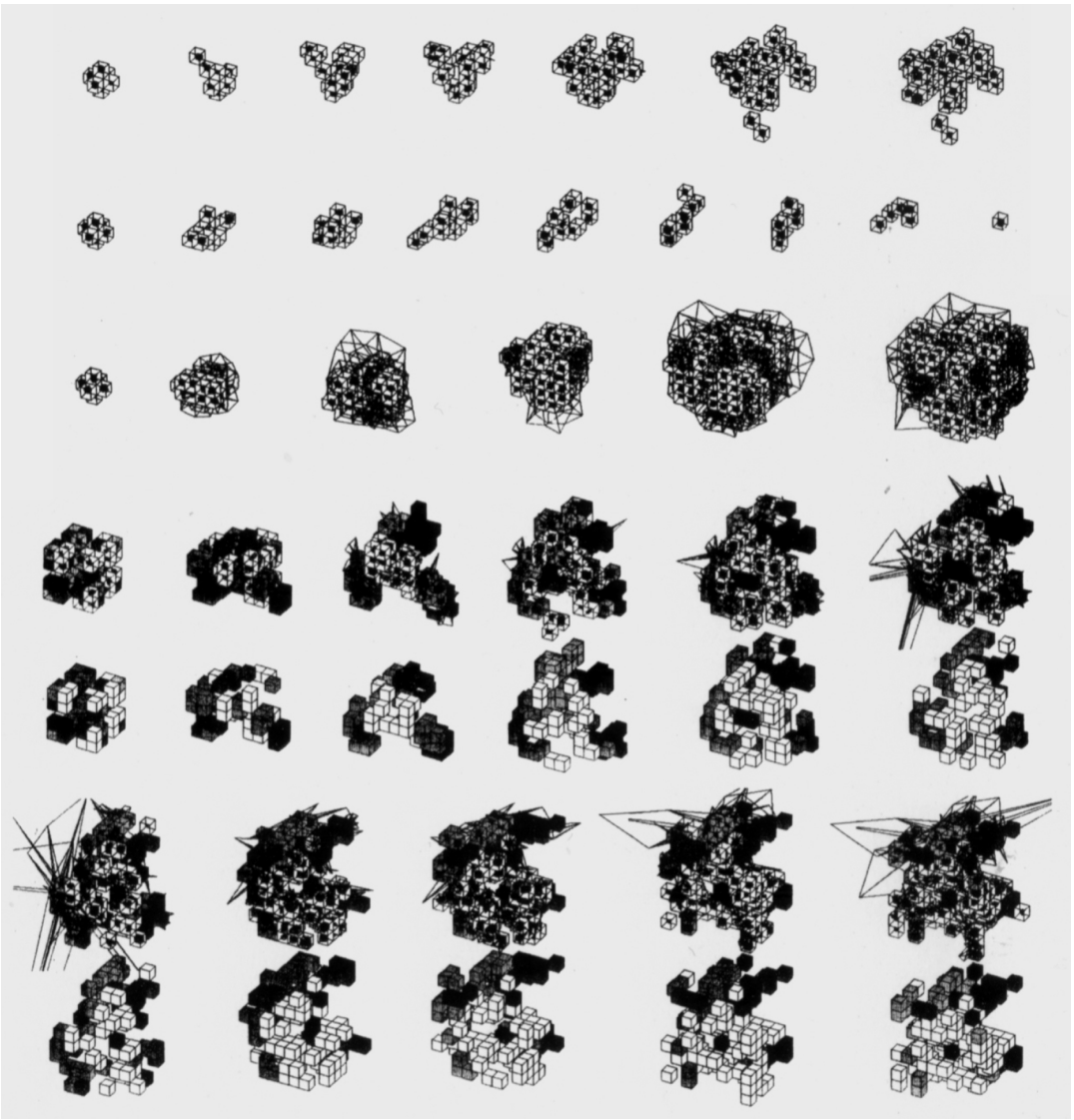


Fig 1:2 Three-dimesional self-organizing constructor. Nagasaka, 1991

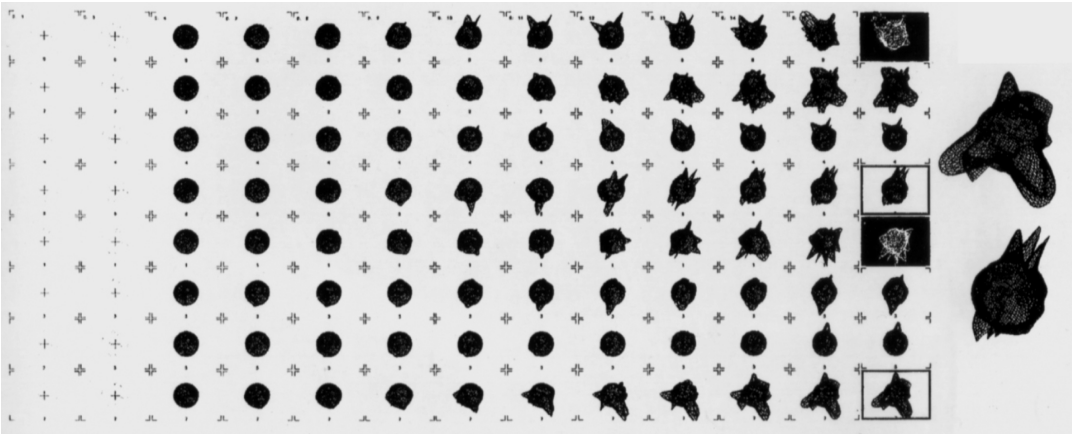


Fig 1:3 Genetic algorithim, Nagasaka, 1992

expansion" of cities such as Taipei, are not apparent in the more organic emergent structure of the medieval cities; the most important issue is the lack of focus. Nangang district, Taipei, is currently undergoing rapid development to provide the city with jobs in the "high-tech" industry, new mass transport systems are being put in place to ferry workers in from residential districts across the city. The process of adding districts with specific functions creates a dependency upon transport while simultaneously destroying and preventing community scale ecologies.

We can find comparative models in nature to discuss cities and their metabolic balance, like wise we can identify biomes with limited diversity and detached systems which can compare to a sprawling city.

A good example of a sprawling, unstable ecosystem is the coral reefs. Despite there being a large number of different species that dwell within coral reefs, the base for the entire ecosystem is a single taxonomy life, the polyps. Like the 'Tells' of early Mongolian and Mesopotamian civilisations, polyps do not digest the previous generation of structure, instead they use the calcified carcasses as the foundation for the next generation. The polyps have a very specific relationship with the surface of the water which must be maintained in order for the polyps to thrive, by building upon the bones of the previous generation the distance from the surface diminishes until coral can no longer grow and the reef dies. Most of the reefs around the world are located upon destructive tectonic boundaries which lower the level of reef over many years before the reef can be repopulated, most natural reefs are built upon the fossils of prehistoric reefs as a result of this process.

As with all Biomes, there is a hierarchy and sequence to the growth of the coral reef eco-system, the polyps are the pioneer organism, propagating topologically suitable areas first, next come the coral flora, which grow upon the calcified carcasses of the polyps, the coral flora provide nutrients and shelter the coral fauna which in turn attract predatory organisms. Coral reefs are fragile biomes as all subsequent organisms are reliant upon the success of the polyp for survival.

"There is an abundance of books with titles like The Cosmic Blue Print (by Paul Davies) or Blueprint for a Cell (by Nobel Laureate Christian de Duve). These however are quick to point out that an architect's blueprint is a specific one-off set of plans whereas the 'blueprint' in nature is a set of instructions which are dependent on a particular environmental context for there interpretations" John Frazer : An Evolutionary Architecture.

The Darwinian evolutionary model uses proliferate production of variations and a brutal process selection too arrive upon 'designs' that maintain a metabolic balance with their environment. The mutation and selection process develops multiple 'designs' within the environment at the same time, resulting in complex structures incorporating systems for growth, death, and recycling of all materials. Death and the re-cycling is of great importance within these natural ecologies, allowing flexibility and responsiveness within the ever changing environments, as is highlighted by John Holland as he deals with the question "How does evolution produce increasingly fit organisms in highly unstable environments?" John Holland : Adaption in Natural and Artificial Systems

For the Biological model to be used effectively we must classify building typologies in order of their role within urban growth.

Pioneering typologies include: Factories and bases for industrial manufacture, trading infrastructure such as ports if topography is suitable, agriculture for subsistence growth.

Secondary typologies include: Residential, whole

sale trade, Business / Commercial and basic retail.

Tertiary typologies include: Retail, services, educational, recreational and governance.

Through understanding the roles that each of these categories play in each phase on growing and adapting the city it is possible to develop a strategy whereby each typology is introduced into the sprawling urbanity at strategic time and locations to ensure that a divers sprawl with space for adaption and regrowth is possible.

The City as a Stable Ecology.

Much like natural ecologies, settlements that are dependent upon a single agent, such as a single industry, for it's income are less able to adapt and survive as the contextual pressures upon the agent change. The coral reef being solely dependent upon growth and propagation of coral polyp for the survival of the Biome means that minimal changes in the temperature, acidity and nutrient levels of the water mean that the whole ecology could rapidly collapse. Much as the coral reefs dependency upon the polyp means that the ecology is fragile and unable to adapt, the same can be said for urbanism, residential settlements constructed to serve specific zoned industries often have limited accessibility connecting primarily to the industrial zone, additionally these areas are fragile as they may be dependant upon a singular form of production. The main issue regarding this type of planned development is that industrial processes are constantly evolving and advancing, once an industry which acts as an attractor for the urban development is superseded the zone ceases to function and the limited accessibility prevents the zone from serving other areas of the city.

This can be seen in the two examples of Liverpool in England and Detroit in the United States. Detroit was planned and constructed as a manufacturing base for the motor industry. As the nature of the motor industry changed (with east Asia becoming competitive with America) Detroit was no longer viable on the massive scale from where it was conceived, as the motor industry left town the supporting urbanity became defunct. Detroit's rapid deterioration is the perfect case study for urban deterioration, falling from its status as Americas 4th largest city with a population of 1.8million, into a derelict city housing 900,000 people where vast zones lay abandoned and empty.

In comparison Liverpool developed as a thriving multi-industrial hub allowing it to survive industrial/cultural progress. Due to its location upon the River Mersey, a key route for the transportation of good around the country, as well as being a key port for imports and exports across the Atlantic. During the industrial revolution the geographical proximity of Liverpool and Manchester was strengthened through the building of infrastructural connections and immigration from Wales and Ireland provide an ample source of employees for labor. Ultimately Liverpool's location is ideal for many functions, from boat building and industrial manufacture and most importantly international trade. Its is Liverpool's location that allows it to support a range of activities, that can adapt to provide stable income as the different activities go through change.

The above examples of two cites focus upon the notion of multi-functionality and accessibility in the macro-scale but it is important to understande that these notions operate without scale, from individual buildings, to the street, neighborhood, up to the village, town, city and metropolis. The success of Liverpool and the failure of Detroit comes down to diversity, the lack of successful secondary typologies in Detroit meant that once the primary typology became defunct, there was no flexibility and whole urbanity failed. On the other hand Liverpool has grown around a range of primary typologies and has successful secondary typologies which allow adaption in response to changes in economic pressures .

Greater Taipei is a mix of the two models of growth discussed above, the historic centre has been built up over time, starting as an agricultural and trading centre, with strong secondary and tertiary typologies. The majority of new growth around the historic centre took place in a very short period (between 40-60) years and was very high in density. The new growth was constructed about a single primary typology, the lack of diversity in both density and functionality has made these areas inflexable and weak in the face of changes in economic pressures.

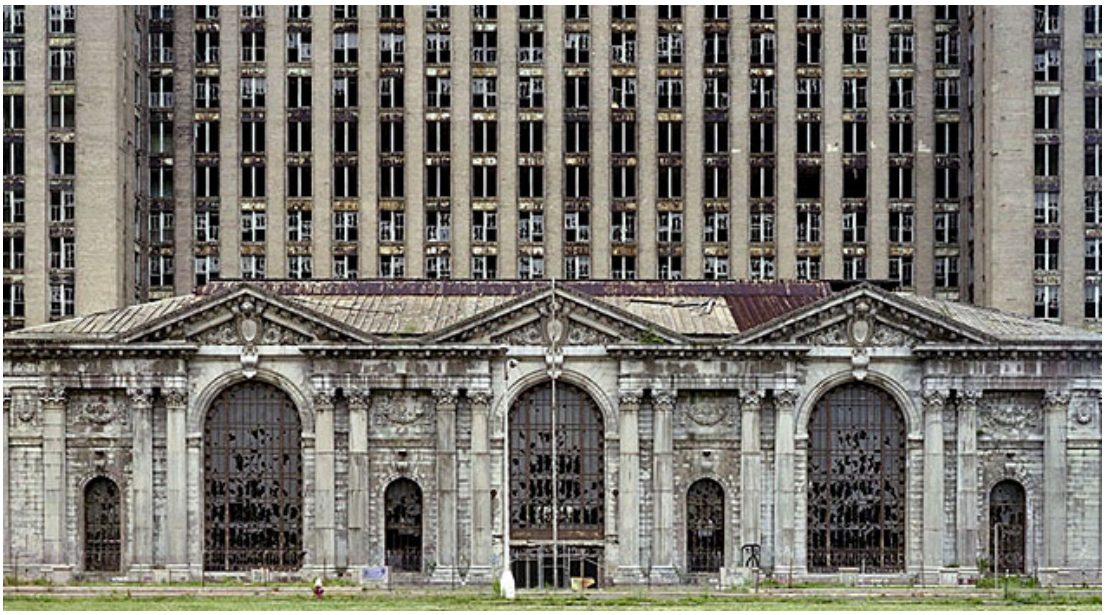


Fig 2:1 Ruins of Detroit

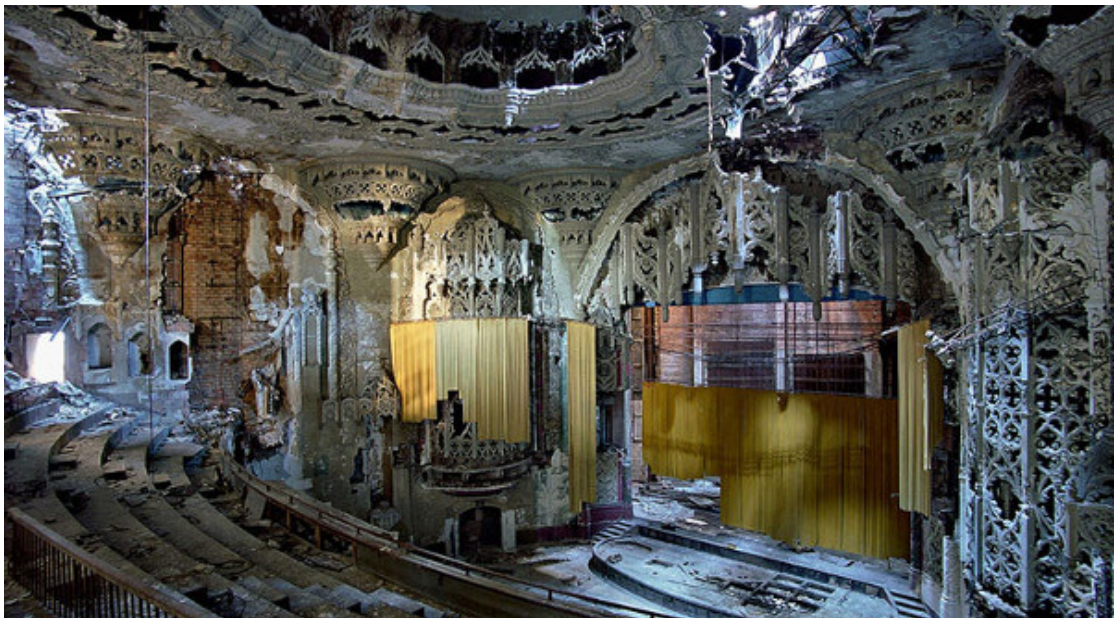


Fig 2:2 Ruins of Detroit

The Modernist City and Mono-Functional Zoning.

The zoned approach, first presented by French socialist Tony Garnier in his 1904 project for "Cite industrielle" aimed to resolve many of the conflicts that had arisen within the traditional city, conflicts between; work and recreation, pedestrian and vehicular, industrial and residential, etc. These urban conflicts where resolved through the creation of zones of function, planned in relation to one another. These are many advantages of the zoned city, by separating the different functions of the individual supply lines can be constructed for each zone improving the efficiency of the city on the whole. Separate circulation routes where provided for vehicular and pedestrian traffic, in theory this provides a calmer less stressful experience for both drivers and walkers.

The zoned approach was conceived during a time where advances in vehicular production where celebrated, zoning forces a dependency on the car as well as presenting the disadvantages associated with mono-functionalism discussed in the previous chapter. As well as constructing new inflexible urbanism, by adding mono-functional zones to established organic cities new problematics can be observed. In "The City Within the City" Leon Krier descusses the process through which mono-functional zoning decomposes the traditional centre, new zoning encourages the migration of industry and residential, from the city centre, to the periphery while the concentration of administration commerce in the historic centre. The city becomes a body with clearly defined zones, the historic centre becomes the weakened heart supporting a massively swollen body.

"Mono-functional zoning can be identified as the most radical instrument in the destruction of European cities. Not only does it promote land and building speculation at the large scale, but it also strengthens the centralizing tendencies of political bureaucracies and justifies the monopolization of commerce. Thus, it destroys the refined and delicate physical fabric of most cities, and it has also become the most brutal means for destroying the social fabric and the complex cultural and economic relationships within the surviving urban community." Leon Krier The City Within the City.
Krier proposal for reconstructing the decomposed city is to re-zone the city, not by function but instead by the comfortable traveling distance by foot. The new zone / quarters are to have strict boundaries between one another and the countryside, each zone is to have its own centre and contrasting typologies are then constructed within the zones to create complex, poly-function urban constructs. Though Krier clearly identifies the importance of poly-functionalism with in the city, the proposal of defined and strict boundaries indicates that the importance of 'sprawl' as a mechanism for urban development has been overlooked. Krier's proposal for reconstructing the city is still planned in the traditional sense and looks to deal with the issues presented by mono-functionalism in a single phase of development. Both Garnier's and Krier's strategies for dealing with urban growth and change fail to embrace sprawl as a natural response to successful urban centre, as a result the health of the urbanity can't be ensured beyond the initial design or intervention.

Poly-centric Cities.

Poly-centric cities are a form of urbanism which is a natural evolution of the city, a "spatial manifestation of the progressive disassociation of activi-

ties and power" (atributosurbanos.com) Many examples of evolved poly-centric cities exist across Eurasia were cities exceed the critical population for a mono-centric structure and competitive sub-centers are established , historians have identified Imperial Rome as one of the earliest example of a city that has undergone the transition from a mono to a poly-centric structure and it suspected that the transition correlates with period where Rome's population first exceeded one million.

There are many advantages to the poly-centric configuration, namely increased accessibility to amenities, increased diversity at a range of scales and a distributed infrastructure. The advantages of the poly-centric had long be identified and in 1898 Sir Ebenezer Howard formalised this with the proposition of the Garden City in "Garden Cities of To-morrow" the proposal is a construction of city centers focused on a capital city, with the sub-cities positioned on concentric rings, interspaced with countryside, the sub cities would be linked by a series of transport arms radiating from the capital city with rings of transport linking the sub-cities on the exterior. The garden city proposal has many disadvantages in comparison to the organic poly-centric city proposition of a central transport hub removes the possibility for the democratic evolution of power by giving dominance to the capital city. The proposal is dependent upon strict boundary conditions in order to preserve the country side between individual centers, this retards and prevents the growth of the city centers beyond the initial phases planned by the designer.

In "the Coopetition Divulged" Koolhaas describes the contemporary poly-centric city as "combining spontaneity and organization in equal measure in order to shape a kind of immense body without organs, under the skin of which hidden rules can however be deciphered that regulate an order adapted to the logic of advanced capitalism". Koolhaas identifies the need for competition between different centers of the city and the democratic distribution of power, this fluid urban construct allows for the adaptiaton and change of these different centers as the pressures upon them change.

Greater Taipei is a good example that illustrates that poly-centric cities should not be designed rather than grown from the initial city centre. In the 1980's new satellite cities where rapidly constructed about Taipei, with the intention that these would act as self contained centers of power, contributing to the metropolis Greater Taipei. In reality these centers where built to quickly and to densely to allow them to adapt to the changes in economic presser and the new cities have become reliant on the historic centre, whilst new mono-programatic zones are planned in the available land around the centre. In a way Taipei has gone through reverse poly-centric growth.

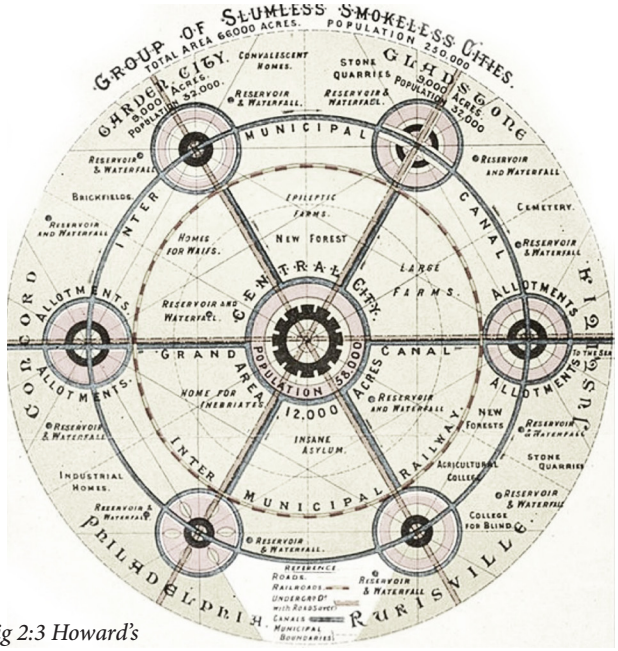


Fig 2:3 Howard's Plans for The Garden City

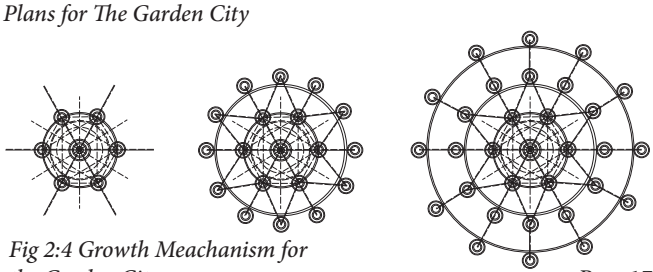


Fig 2:4 Growth Meachanism for the Garden City

The Importance of Sprawl

On the whole the notion of "sprawl" is perceived as a negative, this could be explained by the terms association with an urban form, that of low density suburban developments, shopping malls and industrial estates. It has been proposed by the ISoCARp Congress, in the 2008 conference on European Sprawl, that rather than viewing sprawl as a negative, we should understand that there are good and bad types of sprawl and that it plays an important role in the process of changing the city. Instead of trying to prevent or manage "sprawl", which would be close to impossible in the rapidly expanding cities of East Asia, ISoCARp identifies 3 aims for addressing the issue of sprawl:
Assess and identify different patterns of sprawl in Europe and America.
Test new theories to explain urban sprawl
Create methods by which sprawl can be predicted and shepherded.

When dealing with urban sprawl the aim should not be to retard the cities growth, but rather create multi-functional areas which link into the existing urban fabric, this type of growth cannot be designed but rather grown and encouraged.

In Amy Hellings article "Advocate for a Modern Devil: can sprawl be defended" she illustrates that the spread of low density residential development is a natural progression in response to the advances in communication and transportation technologies. In-fact she argues that the issue raised by sprawl, namely high reliance upon transport and the resulting high pollution, have advanced technologies and policies that deal with the problems, and that further advances will negate these issues.

Helling continues to highlight the advantages of sprawl as: a better quality of life for its residents, providing a greater connection with both urban and rural areas; affordable housing choices, providing larger houses with a longer commute as an alternative to the efficient urban apartment with the short walk to work; and greater social cohesion as residents feel they play a greater role within lower density communities.

Although "Advocate for a Modern Devil" illustrates the positive attributes of sprawl, the phenomena observed and opinions expressed are based upon sprawl within Western, developed countries, where it is focused upon existing metropolitan centers. Sprawl is of much greater concern in regions undergoing rapid development as is Saskia Vendel discusses in "Puc*" (The Chinese Dream; a society under construction), Vendel focuses china where there is an expected internal migration of 400 million farmers towards urban centers between now and 2020, this is the equivalent of "building the whole mass of western Europe within twenty years" Adrian Hornsby, The Chinese Dream

China's Rapid Urbanisation: A New Kind of Sprawl

The rapid industrialisation of China, and the associated shift in its economic make up, has catalysed mass migration from the rural regions. In 2001 the metropolitan centers became saturated and the government instated policies to divert the flow of migrants away from the established centers. The key measures instated where:

To designate 20,000 "small towns" (populations below 100,000 people) as urban and created extensive state employment schemes and career opportunities within these rural settlements.

2)Extensive mono-programatic zoning ; designating 36,000km2 of zones such as
"Economical and Technological development zones" or "High-Tec Development Zone"
within the last 15 years.

(Saskia Vendal: Puk* *The Chinese Dream, Adrian Hornsey*)

The concern with these rules is that they encourage a new type of urban sprawl that is the opposite of western model. Rather than the gradual, low density expansion at the urban fringe, with it's focus upon a developed centre; it is a rapid development focused upon under developed rural centers that is being encouraged. For the reasons already discussed this rapid, mono-programatic expansion raises concerns about the life spans of such 'instant urbanism'. As it can be argued that sprawl within the western context is a necessary mutation of the city, in response to advancing technologies, it can be seen that the rapid urbanisation in China is a natural response to the rapidly increasing industry and to national economic incentives, and as such should not be hindered or retarded but understood and shepherded through the period of its growth. The question is can a combination of spacial analytical techniques, dynamic mappings and growth simulation be used predict growth and identify key locations and typologies which be used as interventions to shepherd the natural growth in such a way that it creates a poly-functional, sustainable urbanity.

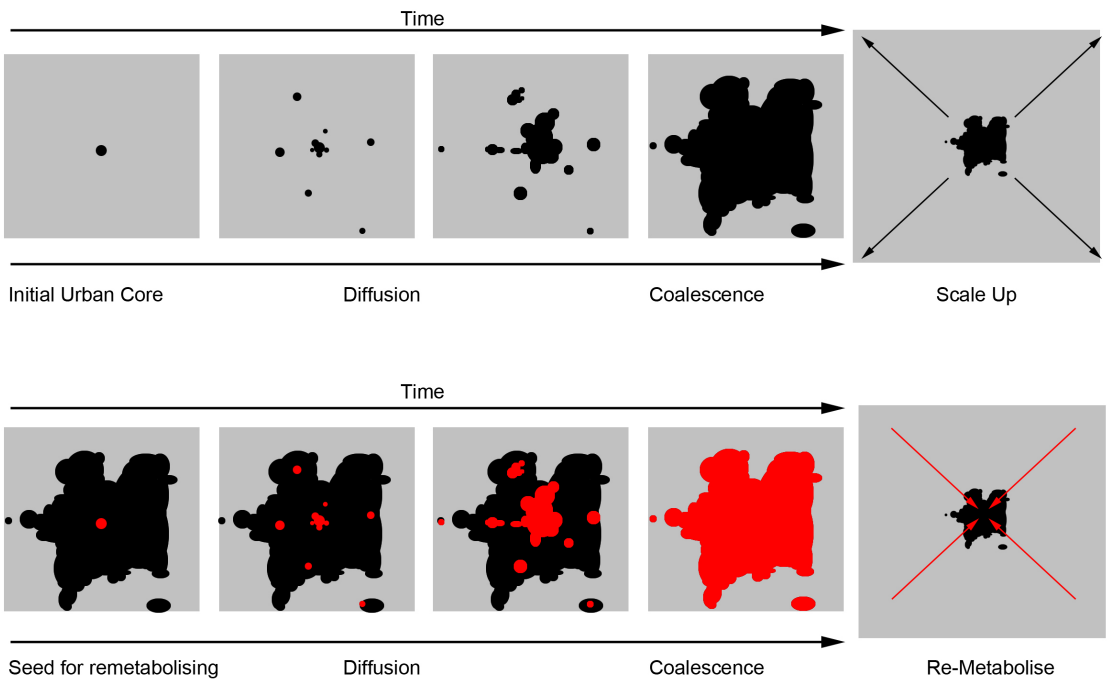


Fig 2:5 Coalescence and Metabolism Diagrams

Mapping Reseach

The mappings record the changes in the 'health' of urbanism as a result of new urban attractors. According to Landry in "Urban Vitality" there are four main categories of data that must be evaluated in order to assess the 'health' of an urban environment:

Subjective measures of subjective phenomena- how safe do people feel about .....

Objective measures of subjective phenomena- a quantaitive measure of action contributed to the way people feel about.....

Subjective measures of objective phenomena- How do people feel about an action/intervention that was initiated because of.....

Objective measures of objective phenomena,- How much of ..... is there in relation to ....

Objective data can be accurately measured categorised and quantified, it is universal.
Subjective data is for assessment, this data will be applicable on a generic level to many situations but in greater detail will be specific to the context in which it was gathered.

Where the effects of two different typologies upon urbanity are compared in two case studies, it is important to focus upon the objective data. The data is presented as mappings of universal, physical indicators of urban 'health' and development.

Though it is important to have data that can be directly compared between the case studies, it is also important to record and synthesise local historic indicators. This will help understand the effects of the 'Attractor' upon the specific locale, instead of assuming that all urbanity operate in an identical manner.

The configuration in which the urban fabric has been constructed, can be used as a good indicator of urban health. This can be seen in the application of the "space syntax" technique, an approach to the analysis and mapping of urban construction developed by Bill Hiller at University College London in the 1960's. The "space syntax" based upon the spaces created and the connectivity across the city at a range of scales. The key relation ship is that between density and accessibility, low density and high accessibility usually result in areas of high crime, on the opposite end of the scale areas of high density and low connectivity get left behind as the city develops, areas of competition draw resources away from areas of low accessibility.

Sprawl in itself is an essential process in growing a city, rather than inhibiting sprawl it should be encourage to develop in a diverse and healthy sequence, that allows for future growth and the formation of new centers of power.

Satellite Imagining and Spacial Analyses

Since the 1960's and the implementation of NASA's Landsat program and the following Spot program in the late 1980's, satellite images and data have been collected and used to build data base of urban and geophysical development. Through the analysis of data collected at regular intervals, either annually or more frequently, allow for the accurate modeling of the urbanisation and change in land use. Historically maps and geographical data bases have become rapidly obsolete, readily available satellite information allows for these data bases to updated with ease, as well as providing information on developing regions where historic data is not available or where the urbanisation process has taken place a such a pace that traditional methods have not been able to record it.

GIS data allows us to achieve the first aim of ISoCARp congress, to assess and identify patterns of

sprawl and the process of sprawl growth, though the combination of GIS data and analytical techniques.

The Space Syntax approach, developed by Bill Hiller at University College London, is based upon the notion that space is constructed from social needs. This process allows for the remote analysis of urban constructs and configurations to distill the key social drivers of development. Through the combination of time-lapse satellite data and the Space Syntax approach, an understanding of local stimuli and there effect on the urban environment over time is gained, which helps to form tools which can accurately predict the effects of any intervention, within the social context, over time.

It is import that the city is read within its context, the great advantage of satellite imaging is that a wealth of different information can be gathered on a full range of scales. Geographic Information System (GIS) are produced through the merging of three main elements that can be produced from the raw satellite data; "time, dynamics and 3D representation, to which must be added the multi-scalar geographical dimension (scales of cartographic representation and images)" Sebastien Gadel, Staphane Fournier, and Emeric Proteau: 3D Dynamic Representation for Urban Sprawl Modeling; Examples of India's Delhi-Mumbai corridor. The dimension of time is modeled through the layering of images/mappings captured at regular intervals and is merged with the appropriate information at each scale. This process often

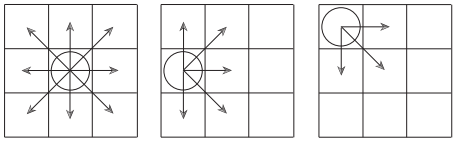
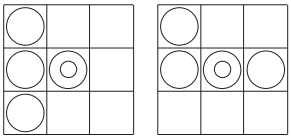
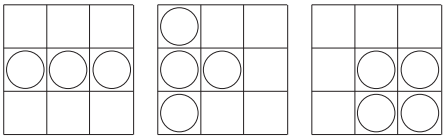


Fig 3:1 Cellular adjacenty diagram

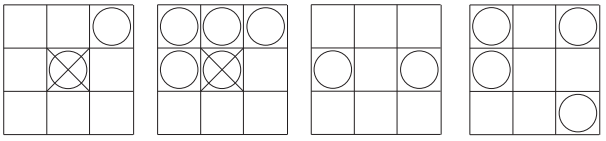
The state of any cell within the CA grid is determined by the states of the neighbouring cells.



A dead cell with three neighbors becomes a live cell



A cell with two or three neighbours survives / is born.



Cells die or remain dead if the area becomes over crowed or the cell becomes/remains isolated.

Fig 3:2 The "Game of Life" basic rules.

In the game of life have two states, alive and dead. The state of the cell is determined by the state of the neighboring cells.

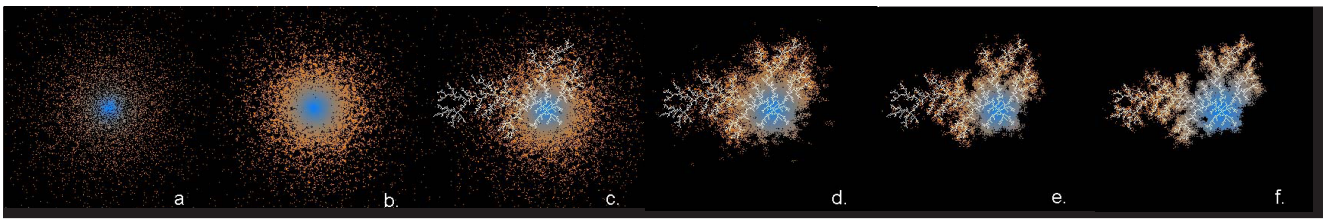


Fig 3:3 Clarkes nurological growth CA simulation

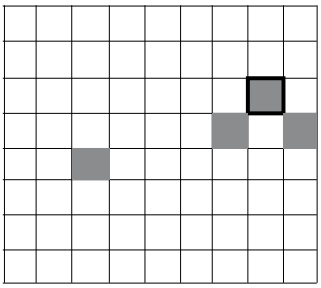
highlights unexpected connections between data sets, creating an insight into regional factors in the growth of the city.

The out put of the GIS systems is still static though, often manifesting as a series of two dimensional, integrated multi-layered mappings, these mapping may be useful as a tool for understanding the drivers in the urban development so far and deliver a far greater wealth of inter-related information than has ever been avaliable before, but they are still a 'snap shot' of a moment in time. GIS alone tell us how a city has come to be rather than giving an insight into what it will become.

Cellular Automata, Growing a Predictive City

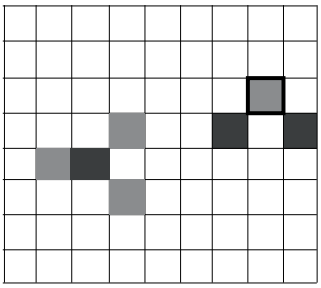
"Cellular Automata are dynamic, discrete space and time systems. A cellular automaton system consists of a regular grid of cells, each of which can be in one of a finite number of k possible states, updated synchronously in discrete time steps according to a local, identical interaction rule. The state of a cell is determined by the previous states of a surrounding neighborhood of cells." (Study Of Cellular Automata Models For Urban Growth; Prof I V Muralikrishna, Prof K V Chalapati)

Cellular Automata models have been shown to replicate the urban growth, through the designation of rules which simulate land use



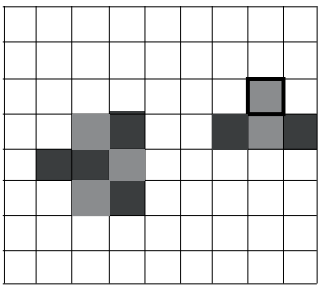
Spontanious new Growth

Draw a location at random. If thi location has at leas one urban neighbor or passes a randomized test of slope sutability, make this a new urban location.
(SLOPE RESISTANCE)



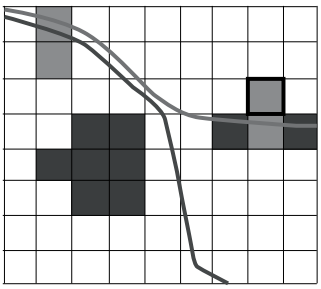
Diffuse Growth and Spread of a New Growth Centre

If the first location chosen is entirely isolated but it meets the test for diffusion constrain and slope, urbanise this cell. Then allow it to become a new spreading centre.
(SLOPE RESISTANCE, DIFFUSION, BREED)



Organic Growth

For all cells with at least three neighbors, and repeating under the spread constraints, if the slope test is passed, make this a new urban location.
(SLOPE RESISTANCE, SPREAD)



Road Influenced Growth

Select a new growth location at random, and repeating according to the diffusion coefficient, search outward a given distance. If a road is found, move to road and along it a distance half of the
diffusion coefficient, then spread to enough neighbours to ensure new growth from this location
(SLOPE RESISTANCE, ROAD GRAVITY, DIFFUSION)

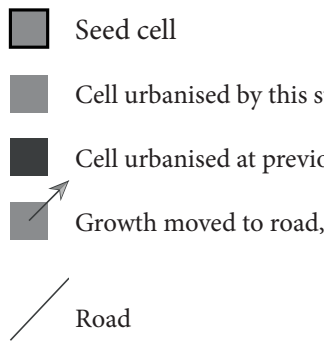


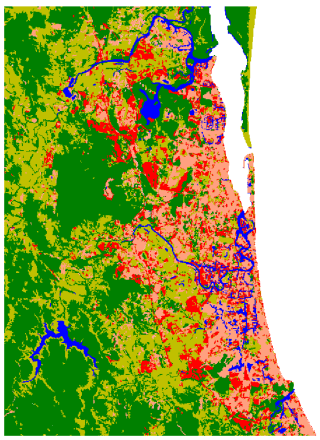
Fig 3:4 Clarkes rules for cellular growth in the San - Fransico Bay area simulation.

designations, and restrictions based upon topological conditions. In 1997 K.C. Clarke showed that CA can be accurately programed to replicate the process of urban growth in his study "A Self-Modifying Cellular Automaton of Historical Urbanization in the San Francisco Bay Area,". In Clarks model the basic CA rules were adapted to take into account a hierarchy of locations as attractors for urban growth based upon topological conditions, hard infrastructure based on previous growth and historical settlements. The rules basic model was also adapted to provide replants again based upon topological restraints and the rules of the previous phase of growth. Though Clarke's model was successful in proving the application of CA for predicting urban growth, the simple set of rules only allowed for the prediction of outward growth, and due to the static nature of the previous phases of growth, the model can only be used to assess the growth of the city on the macro scale.

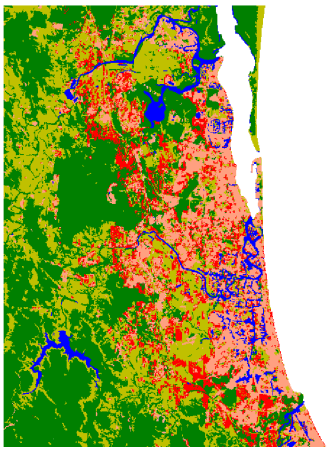
For the CA model as an analytical tool for assessing the effects of an intervention upon to existing contextual condition, new rules needed to instated to account for the decay and metabolism of the previous phases of growth. In 1999 case-study "An optimized cellular automata approach for sustainable urban development in rapidly urbanizing regions" (D.P Ward et al.) a CA model was developed to analyses urban growth at a range of scales. The 'optimised' CA is inclusive of the rules developed in Clarke's 1997 model and elaborated upon them with the introduction of new rules for decay and redevelopment, based economic, socio-physical and inter-ethnic factors. Clarke integrates biomimetic models of the growth and attraction of neural pathways, as the basis for the development of primary transport networks and subsequent attraction of urban development. Through the integration of neurological model, a relationship between transport networks and urban development is established where the growth of urbanism is not dependent upon the transport network but instead its density is influenced by the proximity to the network.

Ward proved the model by programing the historic land-use designations, within the topological and urban context, for the Gold Coast between 1988 and 1995, the resulting simulation mirrors with great accuracy the actual development of the region.

As stand alone processes GIS systems are effective resources for obtaining and evaluating information on existing urbanities, and is a key tool for identifying areas in need of intervention. Having identified the location for intervention CA processes can be used to predict the effect of the intervention upon the existing context, through the repetition of the processes (using GIS to evaluate the CA prediction and CA to predict further growth etc) an understanding of the interventions effect upon existing and future context can be achieved.



Historic Growth



Simulated Growth

Fig 3:5 Historic and Simulated growth in the San-Fransico Bay area

Taipei Case Study.

Taipei is the Capital city of Taiwan, located in the north of the country. Taipei has undergone several very distinct phases of growth as a result of changing economic pressures upon the city as well as different cultures and governments dictating the planning and growth strategies.

Early Aboriginal settlements where attracted to the region by the Danshui river and the fertile land of the river basin. Between 1624 and 1662 under Dutch rule the established settlements where expanded due to there strategic position for trade with Portugal.

Between 1895 and 1945 Taiwan was under Japanese rule, during this period the established settlements where united by a regular grid, the core forming what is now the Zhongshan District.

By 1950 Taiwan was still comparatively compact relying heavily on the fertile land of the basin for agriculture growing vast quantities of tea and spices for european trade. Between 1950 and today Taipei has undergone a rapid process of industrialisation. The promise of employment within this new industrial centre acted as an attractor and catalysed internal migration on mass, from the rural countryside to the urban capital.

During the 1960's became an international exported of electronic goods and the "Made in Taiwan" brand was established. The mass production of these goods for export,was achieved by producing goods,in factories and homes. The slogan "every living room is a factory" was popular during this period as the nation strove to gain an economic presence on the global stage. It is during this period that Taipei began to sprawl to house the new migrants.

During the 1980's planners felt that Taipei was becoming saturated, and the decided to establish the satellite cities of Zhonghe, Banciao, Sinjhung, Sanchong and Lujhou on the opposite sides of the Danshui. Typically these satellite cities have extremely high population densities, the fabric of these cities is made up mostly of residential and light industrial areas, though the distinction between the two types isn't clearly defined. The ground floor of many residential blocks, are used for the manufacture if LED lights, electrical wire and so on. During Taipei's light industrial period these satellite cities would have acted as compact residential / industrial centers feeding the centre with goods for onward trade.

Today the economic pressures upon Taipei have changed, the city is no longer reliant upon light industry, instead the city is constructing an economy based upon high-tech products and cultural trade. Consequently the light industry is disappearing from the satellite cites whilst regions for high-tech manufacture are being constructed in the Nangang district.

The main issue surrounding highly dense sprawl with integrated industrial and residential construction is that once the need for the industrial process dwindles, the satellite cities cease to be compact centers of commerce, instead they have become highly dense regions on the periphery of taipei. In a way Greater Taipei has reverted from a poly-centric Metropolis into a vast Mono-centric City.

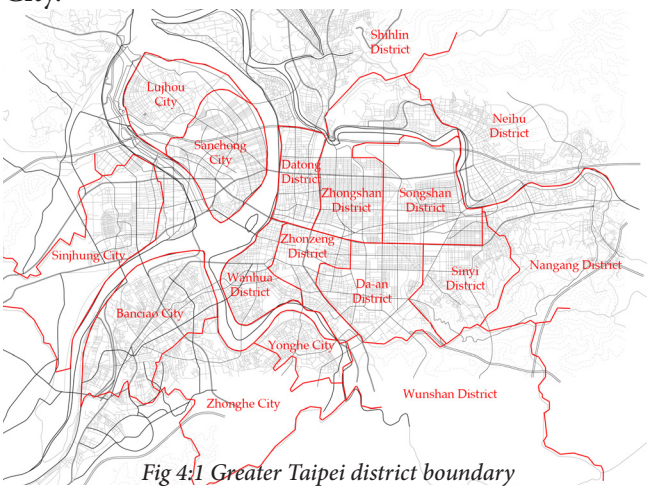


Fig 4:1 Greater Taipei district boundary

Fig 4:2 Taipei Growth sequence

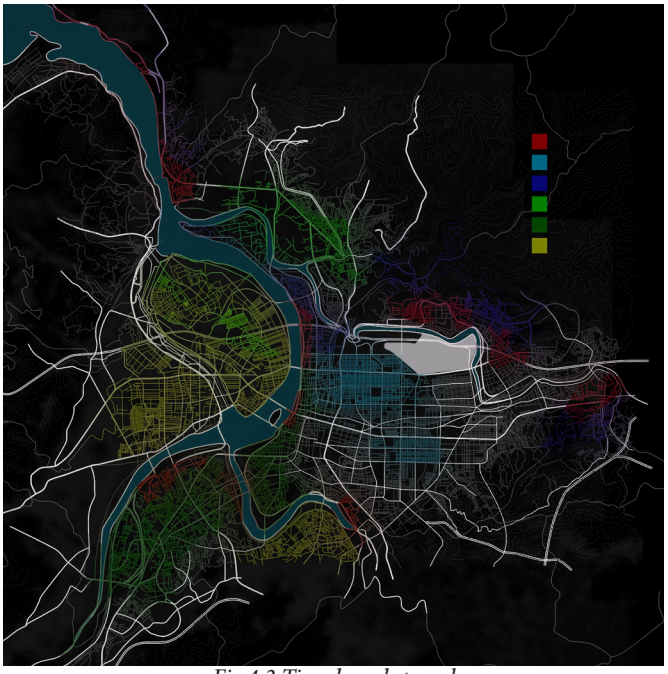


Fig 4:3 Time based sprawl

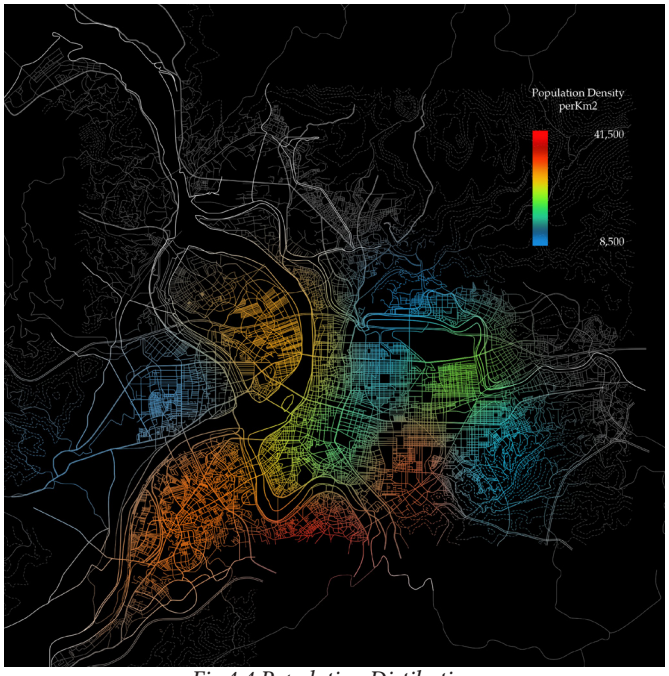


Fig 4:4 Population Distibution

District _ Population_Area
2006

daan _ 27,546_
Datong_22,357_
Wanhua_21,958_
Songshan_20,870_
Zhongzeng_20,856_
Xinyi_20,612_
Zhongshan_15,962_
Neihu_8,349_
Wenshan_8,264_
Shilin_4,617_
Beitou_4,382

Taipei Mapped

In this section connectivity mappings are used, in conjunction with satellite images and government data on population growth and distribution, too evaluate the 'health' of the urban fabric and identify areas for strategic intervention. The 'urban health' of the areas highlighted by this process can be verified through the use of "street view" for remote visual assessment.

Fig 4.5 identifies the six main types of urban construction found in Greater Taipei, this helps understand what forces drive the development of the cities different regions.

1: Light Industrial / Residential mix. This type of construction is most commonly found in the satellite cities of taipei,

2: Morphed grids. These constructions are found upon the fringes of the japanese grid, the grain of these areas is usually much tighter than the original grid and the axis morph into more organic constructions.

3: Japanese grid. Large regular blocks typically populated by large high-rise buildings, these areas have a comparatively large amounts of green space, indicating a higher concentration of educational establishments in these areas.

4: 1970's planned city. three areas on the outskirts of Taipei where planned in the 1970 around the concept of creating seven neighborhoods within each of the designated areas. The result of these interventions are areas of low conectivity between central taipei and and the subsquent phases of sprawl.

5: New interventions. The area shown is the redeveloped 101 area, this area houses many key buildings such as the town hall, national library and the 101 itself. The construction uses a regular

1: Sanchang City, Light Industrial
2: Xiemen District, morphed urban grain
3: Zhongshan District, Japanese grid
4: Yonghe City, 1970's neighborhood planning
5: Sinji District, regenerated 101 area
6: Songshan District, low density suburbia

Fig 4:5 Common urban configurations found in Greater Taipei

grid much the same as the japanese grid but with a much larger block size.

6: Suburban developments. Usually constructed using an imported western model, these areas are typically low in density and accessibility as a result of difficult terrain.

To gain a greater insight into the health of city, connectivity mapping will be carried out at a macro-scale and then areas of interest will be mapped at a neighborhood scale to assess the effects of new interventions.

Connectivity mapping of Greater Taipei on a macro scale highlights four area of high accessibility (5,6,7,8 fig 4.6) in the Zhongshan, Songshan and Da-an districts, by cross referencing the macro-connectivity (fig4.6) map with the population distribution map (fig4.4) that these areas have high-population densities with the Da-an district having the highest density in Taipei. The combination of high density and high accessibility indicates that these areas have a good 'urban health'.

Through the cross-referencing of the two maps an area of 'good urban health' is highlighted Shihlin District, this area is the opposite of areas discussed prior, it has a low connectivity and a low density, "street view" verifies that this area is a low density light industrial region.

Areas 1,2,3 fig4.6 typify the configuration of the satellite cities. The connectivity mapping shows that these regions have mid to low connectivity and the population distribution mapping (fig4.4) indicates that these areas have some of the highest densities in Greater Taipei. Visual assessment confirms that areas are high density residential / light industry.

Through cross referencing the historical growth map (fig4.3) with the connectivity map (fig4.6) we can see that the urban areas of success where either constructed during the japanese occupation or are a continuation of the japanese grid. The assumption is that in later phases of growth the Da-an region acted as the main urban attractor and the initial areas of growth have been replaced with new high density constructions over time.

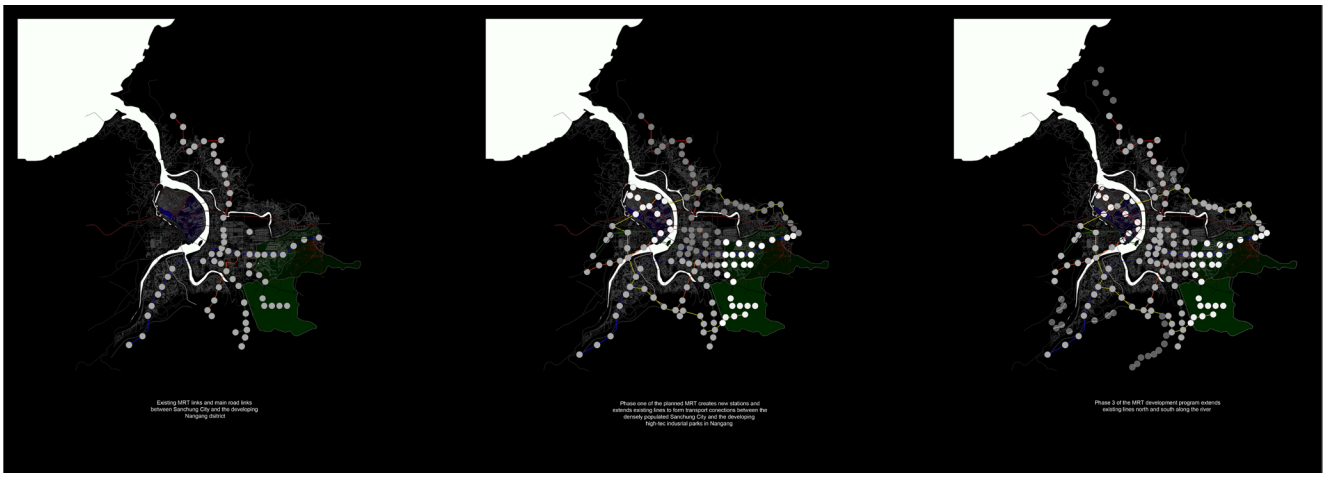


Fig 4:5 Planned extensions to the Mass Rapid Transport system
New routes implemented to create links between historical center and defunct satellite cities

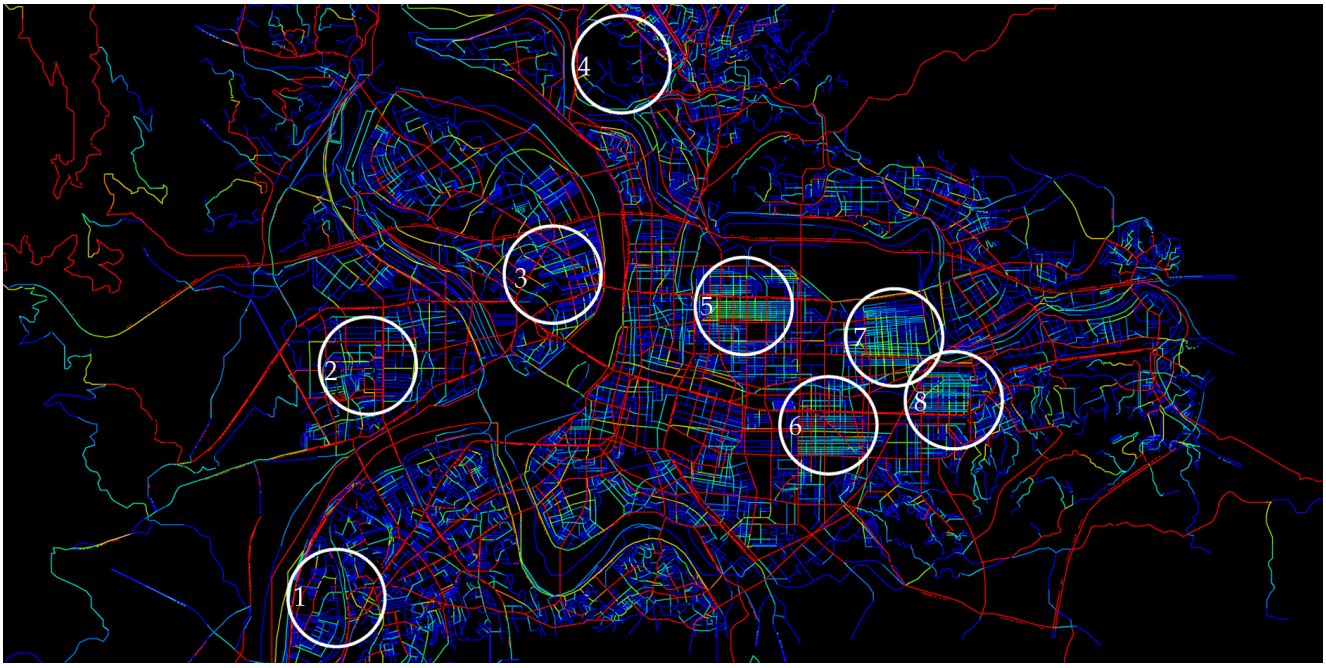


Fig 4:6 Existing connectivity of the Greater Taipei area

1: **Banciao City**
high density, low accessibility
light industrial residential mix
poor urban health

2: **Sinjhuang City**
mid density, mid to low accessibility
residential
mid urban health

3: **Sanchung City**
high density, low accessibility
light industrial residential mix
poor urban health

4: **Shihlin District**
low density, low accessibility
light industrial
good urban health

5: **Jhongshan District**
high density, high accessibility
commercial residential mix
good urban health

6: **Da-an District**
high density, high accessibility
commercial residential mix
good urban health

7: **Songshan District**
high density, high accessibility
commercial residential mix
good urban health

8: **Nangang District**
high to mid density, mid to high accessibility
commercial, light industrial, residential mix
mid urban health

Fig 4:7 Street view verification of the area's of interest

Assessing Predicted Growth.

Having identified problem areas within the existing the next phase is to assess the effects of new urban attractors upon growth in these regions and consequence upon accessibility and density. Urban growth will be assumed using the same patterns and principles established by Clarkes "A Self-Modifying Cellular Automaton of Historical Urbanization in the San Francisco Bay Area". Namely Slope resistance and attraction too existing infrastructure and urban fabric.

Three different types of intervention are examined for each of areas, all based upon an urban attractor with a limited life span, over two phases of growth.

The first type of intervention are exterior to the established urbanity, with the aim of forming new connections between the "problem area" and the new attractor, that these connections will tie into the existing fabric on a larger scale and accessibility to the area will be increased.

The second type of intervention are positioned on the fringe of the existing urbanity, the hope in this scenario is that the new attractor will catalyze a redevelopment of the failing areas as well as producing new areas of sprawl too the exterior of the existing fabric. The redevelopment of the interior could improve interior accessibility at the neighborhood scale whilst new growth to the exterior could create new connections and improve accessibility on the macro scale.

The third type of intervention are to replace failing constructs within the 'problem areas' with the new attractors. The aim of this intervention would be to densify the region whilst increasing internal accessibility, with minimal new growth to the exterior of the existing fabric.

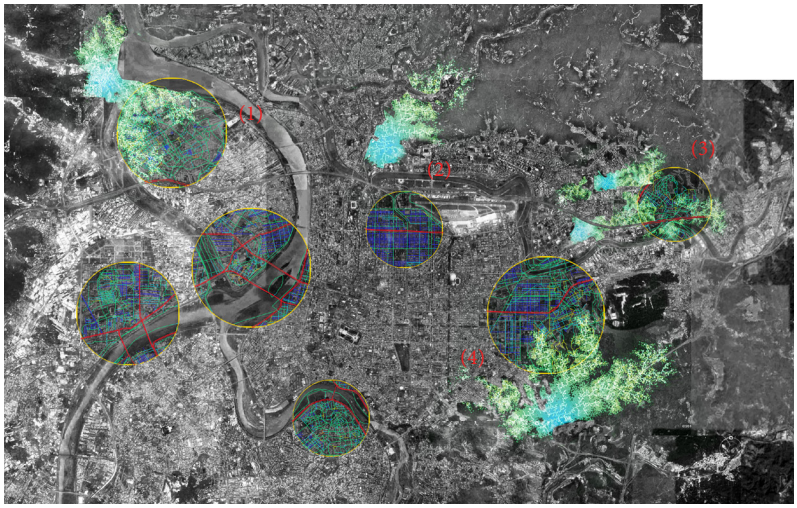


Fig 4:8 Attractors external to the studied neighborhood.

1st phase of growth

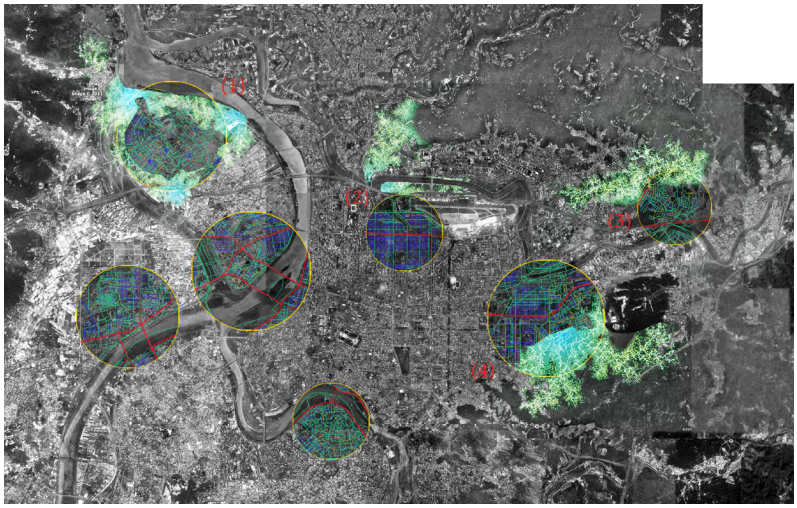


Fig 4:9 Attractors on the boundary of the studied neighborhood.

1st phase of growth

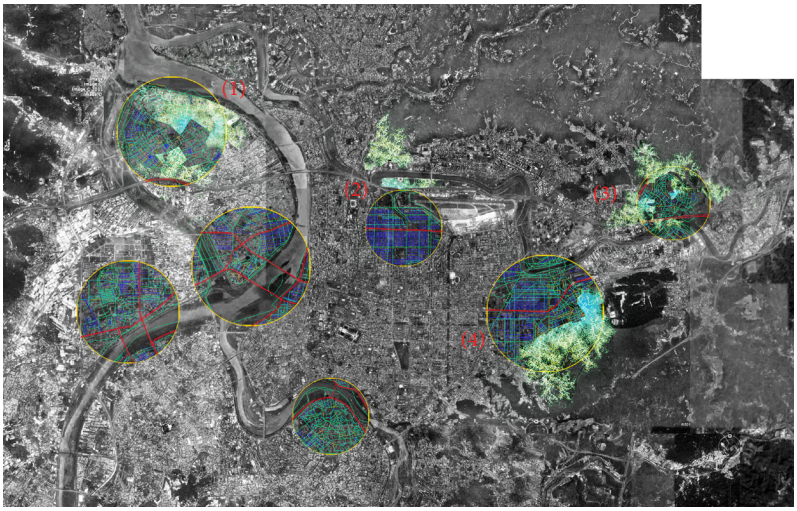


Fig 4:10 Attractors on the interior of the studied neighborhood.

1st phase of growth

First Phase of Growth.

Exterior

(1) Growth has spread predominantly towards the existing urbanity and has metabolised the failing light industrial areas around the fringe of Lujhou city, due to topographical restraints of area. The majority of the growth away from Lujhou city takes place along a strip of flat land between the sloped terrain and the Danshui river.

(2) The urban growth sprawls away from the city centre filling in the moderately sloped terrain between the areas of sprawl formed around the river tributaries. As a result of the moderate terrain the urban configuration in this area is expected to be mid density.

(3) The growth sprawls in much the same way as in area (2), due to greater topological restraints the densities of the new growth is expected to be low.

(4) Growth sprawls away from the attractor along the established infrastructure, terrain restraints inhibit growth to the south, new growth is stimulated on the fringes of the established urbanity again focusing on the existing infrastructural connections.

Boundary

(1) Three attractor are placed in failing areas around the exterior of Lujhou and Sanchong cities. Growth is metabolizing failing light industrial areas around the fringe of the established fabric. Little growth has taken place out side of the existing boundries. The growth in this region is expected to be very high in density matching the surrounding fabric.

(2) The pattern of growth is much the same as was seen in the exterior attractor in this region.

(3) Again the pattern of growth in the region is much the same as in the exterior test except with greater sprawl towards north on the flatter ground, due reduced topographical pressure in this area the density of the new growth is expected to be of mid density.

(4) The attractor in this area has been placed on the fringe between the established sprawl to the north and flat open land towards the south. As a result of weak restaints rapid growth has taken place in this region, spreading along the fringe of the established fabric and making links with the existing infrastructure. As a result of weak restraints growth in this area is expected to be of hight density.

Interior

(1) Attractors are placed within failing areas of the existing fabric, the attractors catalyse a redevelopment of the redundant light industrial areas, regrowth is focused upon the infrastructural arteries in the area.

(2) The attractor encourages redevelopment of the immediate local, though the avaibility of land to the north encourages new growth here, much the same as in the previous mappings.

(3) New growth is encouraged in the least topographically suitable areas, forming links with the fringes of the existing sprawl.

(4)The new attractor encourages the redevelopment of weak fabric on the fringe of this region and expands into the open space where available.

First Phase of Growth Analysis.

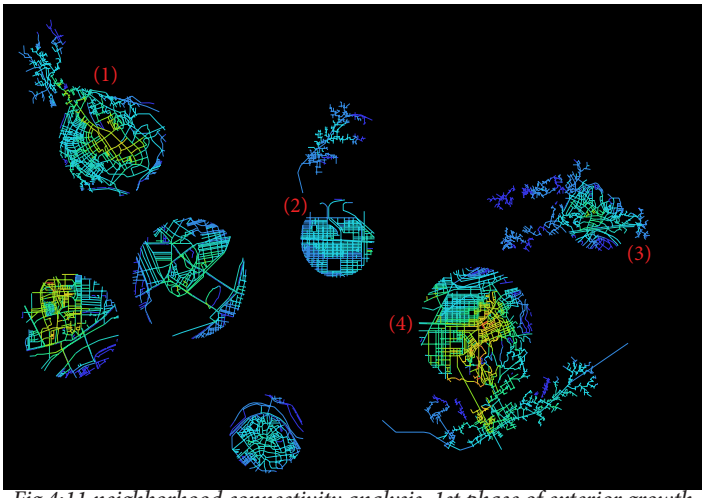


Fig 4:11 neighborhood connectivity analysis, 1st phase of exterior growth

Exterior

On a neighborhood scale areas 1 and 4 create diverse sprawl, new growth to the exterior of the established urban fabric creates new connections to some of of the problem areas in the interior of the region. The diversity between high connectivity and low connectivity is desirable as it allows flexibility in further stages of growth as well a options in the kind of construction erected. Areas 2 and 3 continue the established trend of growth in these regions.

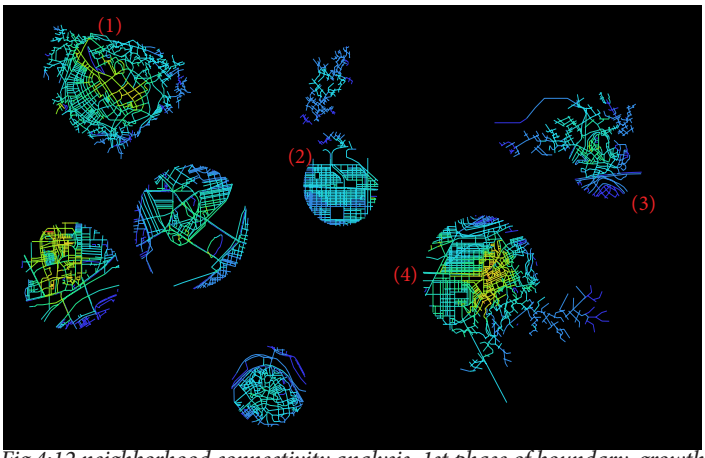


Fig 4:12 neighborhood connectivity analysis, 1st phase of boundary growth

Boundary

Areas 1 and 4 have increased accessibility to the centers as well as low connectivity sprawl to the exterior. The effects on connectivity and sprawl are notably less than those of the exterior attractor but the results are far more compact. As was seen in the external attractor test areas 2 and 3 continue the established trend of growth in these regions.

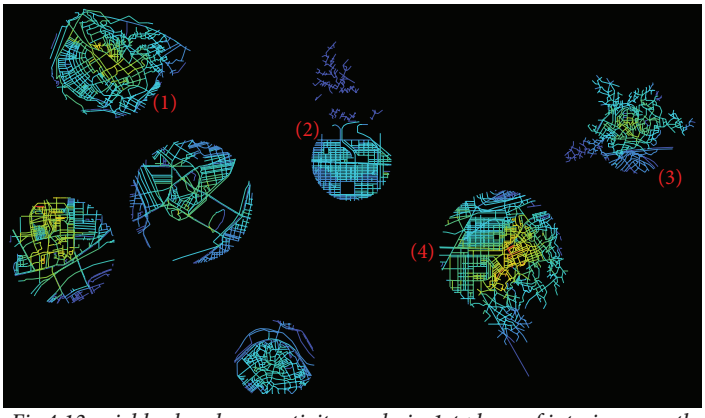


Fig 4:13 neighborhood connectivity analysis, 1st phase of interior growth

Interior

In all areas the urban sprawl has been dramatically reduced in comparison to the interior and boundary mappings. In areas 3 and 4 the improvements to connectivity within the high density fringe has been greatest out of all three mappings.

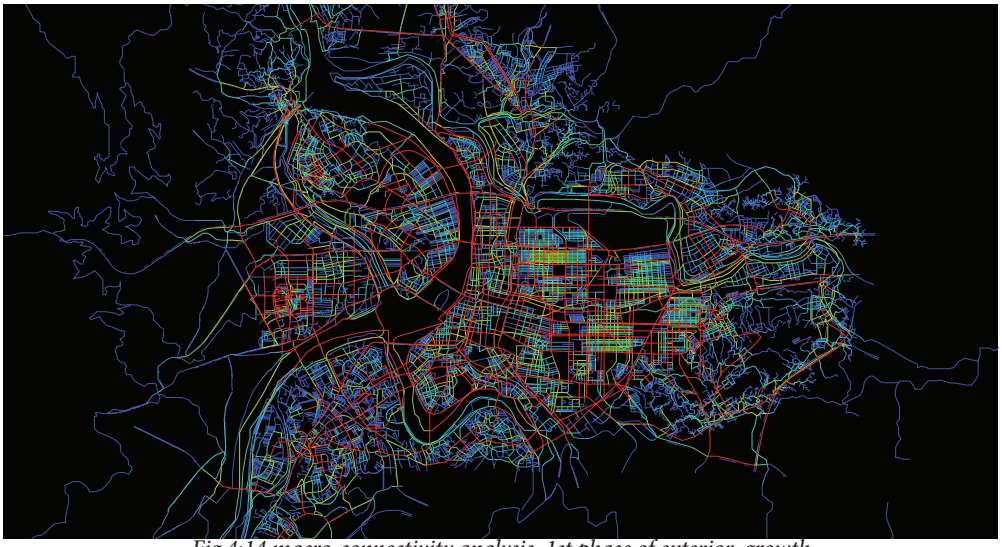


Fig 4:14 macro-connectivity analysis, 1st phase of exterior growth

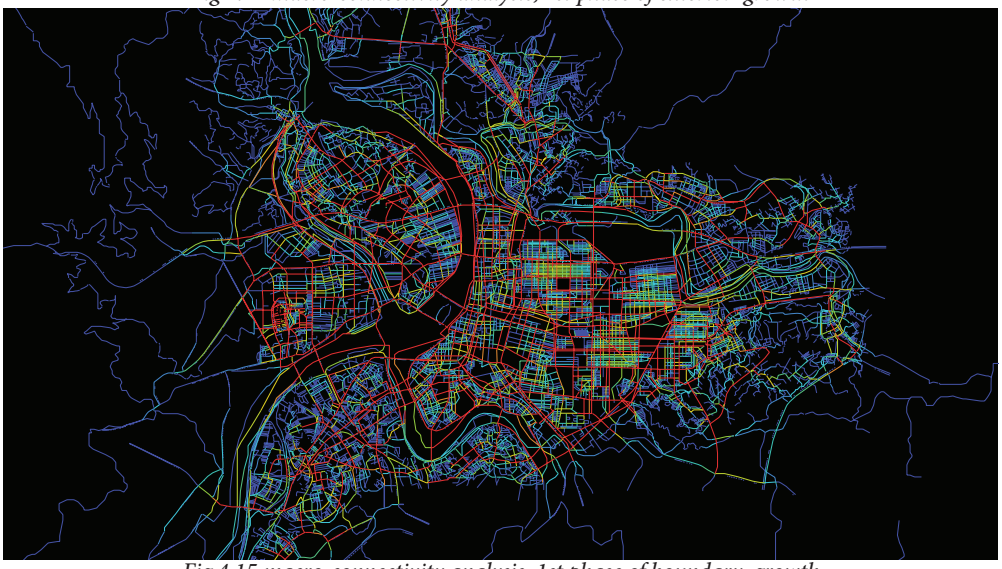


Fig 4:15 macro-connectivity analysis, 1st phase of boundary growth

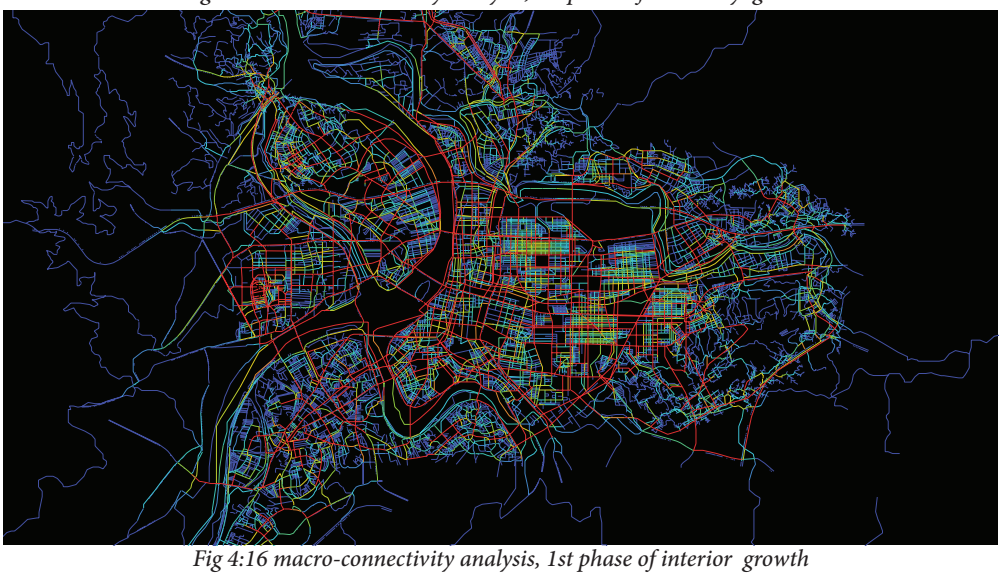


Fig 4:16 macro-connectivity analysis, 1st phase of interior growth

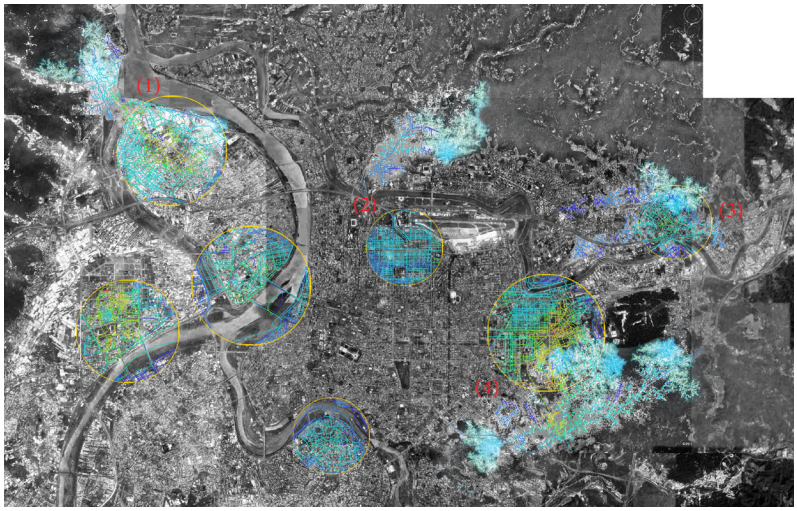


Fig 4:17 Attractors external to the studied neighborhood.

2nd phase of growth

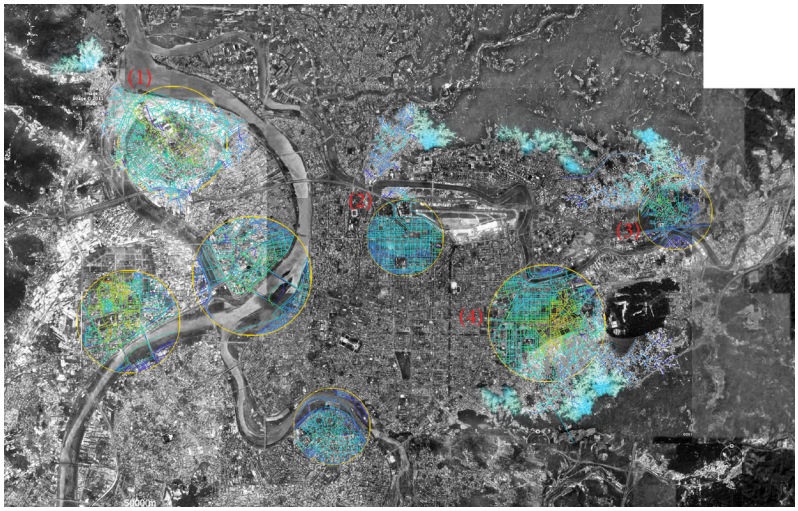


Fig 4:18 Attractors on the boundary of the studied neighborhood.

2nd phase of growth

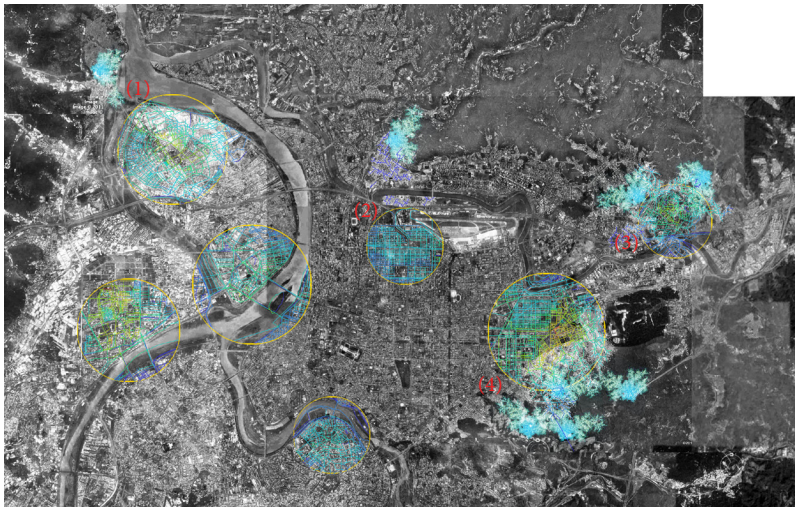


Fig 4:19 Attractors on the interior of the studied neighborhood.

2nd phase of growth

Second Phase of Growth.

Exterior-new attractors are placed to the exterior of the previous phase of growth, to encourage new sprawl outwards.

(1) Terrain restrictions and established urban fabrics in this area prevent any significant sprawl. Instead of sprawling new growth has taken place with the failing light industrial areas of the interior.

(2)The new attractor in this area has encouraged new growth that mimics the first phase of growth in this area, filling in the available space and creating connections between the two existing arms of sprawl.

(3) There is limited sprawl in this area as a result of topological restraints and low accessibility, the growth that has taken place in this area sprawls outwards from the point of attraction along terrain with the least resistance.

(4) Three attractors in this area encourage significant new growth, spreading primarilary along the existing infrastructure and the new connection established in the previous phase of growth. The majority of available land in this area has now been filled and the new sprawl is inhibited by terrain resistance to the south and established sprawl to the north, east and west.

Boundary -new attractors are placed on the periphery of the first phase of growth.

(1) Again in this area terrain restrictions and established sprawl inhibit new growth, the second phase of the growth in this area is much the same as that for the exterior attractors.

(2) New sprawl in this this area is not as prolific as the first phase of growth instead the fringe of the previous growth has become more developed. The new sprawl in this area follow the same trend as the previous phase of growth creating new connections between the two arms of sprawl that have developed along the river tributaries.

(3) The majority of new growth in this area has taken place in the same areas as was seen in the exterior mappings, as well as this growth, increases in connectivity have encouraged new growth upon existing sprawl within the proximity of both areas (2) and (3).

(4)The majority of growth in this area takes place along the existing infrastructure filling in the gaps in the previous phase of growth which too place along the periphery of the existing sprawl.

Interior - new attractors are placed within the previous sprawl and the existing urban fabric.

(1) This area sees no new sprawl instead all new growth takes place within the existing fabric and the first phase of growth.

(2) New growth in this area is significanty less than was seen in the both the exerior and boundary mappings. In comparison to the previous mappings the growth in this area compact, but the growth focuses predominantly on the northern arm of the existing sprawl failing to create the connections seen in the previous mappings.

(3) Growth in this area creates new connections between the previous phase of growth and the existing sprawl. The fringe areas are redeveloped and some sprawl takes place in the land with least topographical restrictions.

(4) New sprawl in this area focuses on the existing infrastructure and the new links into the interior where two phases of attractors have been positioned. The sprawl over two phases of growth in this area is notably more condensed than that of the external and boundary tests.

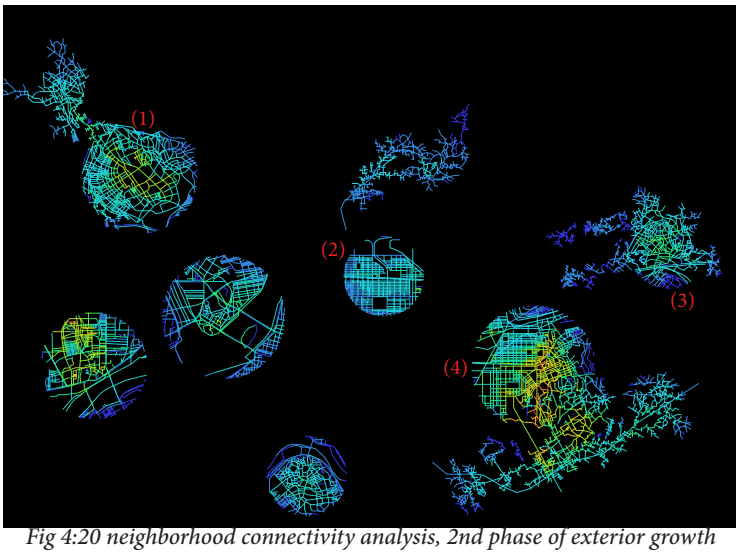


Fig 4:20 neighborhood connectivity analysis, 2nd phase of exterior growth

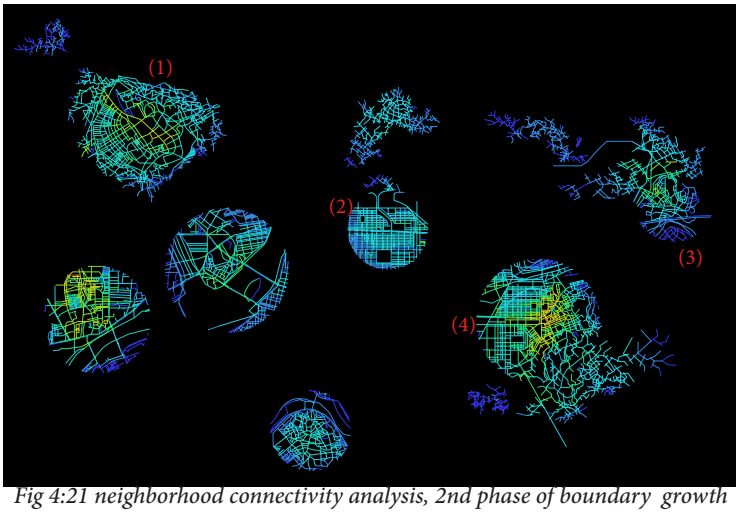


Fig 4:21 neighborhood connectivity analysis, 2nd phase of boundary growth

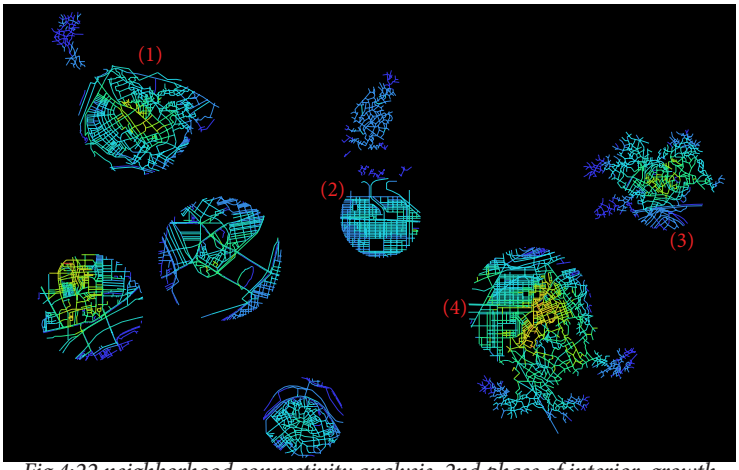


Fig 4:22 neighborhood connectivity analysis, 2nd phase of interior growth

Second Phase of Growth Analysis.

Exterior - the second phase of growth in area 1 has little effect upon the connectivity of the local either at a neighborhood scale nor the at the macro scale.
On the macro scale area 2 sees great improvements to connectivity as the new sprawl creates links between the two arms of the established sprawl.
Area 3 sees limited changes in neighborhood connectivity with slight improvements to the orginal centre, on the macro-scale the new sprawl creates a few new connections between existing sprawl, but not enough to dramatically increase the connectivity of this low density area to the point of poor health.
After two phase of growth area 4 sees the most prolific and diverse sprawl in in terms of connectivity, on the neighborhood scale, out of all study areas in all of the mappings. On the macro-scale though there is little improvement to the health of the existing sprawl, this is most likely because the sprawl in this area is condensed and the new growth only effects the fractured fringe, rather than stitching together diffused areas.

Boundary - In comparison to the exterior mappings, connectivity on both the marco and neighbor hood scale is less significant, this is an indication that there is insufficient land available in the areas of failing light industry to effectively restructure the neighborhood.
Area 2 has a similar mass of growth as was seen in the exterior mapping, though the new growth is considerably more condensed in its reconfiguration. On the macro-scale the boundary attractor have less effect upon connectivity than the exterior mapping, though this sort-fall would almost certainly be dealt with in the next phase of growth.
Area 3 in the boundary mappings is the most

successful in this area. The new growth has improved connectivity within the greater context without increasing the connectivity of the neighborhood to the point where it is unsuitable for the density of the area. The increased connectivity of the existing context has also stimulated new sprawl in area not directly associated with the attractors.
The second phase of growth in Area 4 sees little improvement to the connectivity beyond the first phase of growth. Overall the improvements connectivity and diversity of the sprawl, on both neighborhood and macro-scale, in this area are notable less significant than those witnessed in the exterior attractor mappings.

Interior - The results of the second phase of growth in area 1 is very similar to those seen in the boundary mappings, except with marginally improved connectivity to the interior, as indicated before this is most likely to be due to a lack of space to reconfigure.
Area 2 in the results for the interior attractor are the least desirable out of any of the areas in all of the simulations. There is very little diversity within the new growth and the connectivity within the existing context sees little to no improvement, it can be reasoned that this growth pattern is a result of the area in which the attractors are placed already acts as an urban attractor and the most appropriate land for growth has already been populated by previous phases of growth.
Area 3 of of the interior mappings, on the face of it, appears to be the most successful of all the mappings in this area, upon closer inspection the high connectivity produced by the new growth is inappropriate for the low density configurations expected due to terrain restraint in the

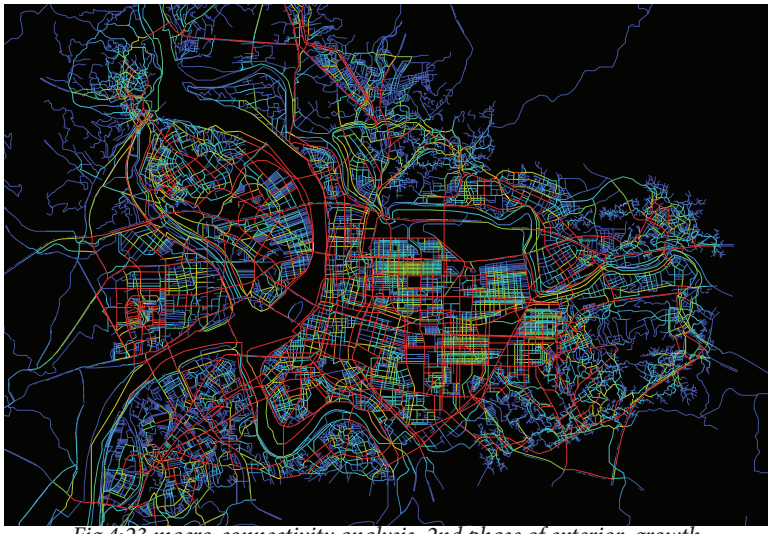


Fig 4:23 macro-connectivity analysis, 2nd phase of exterior growth

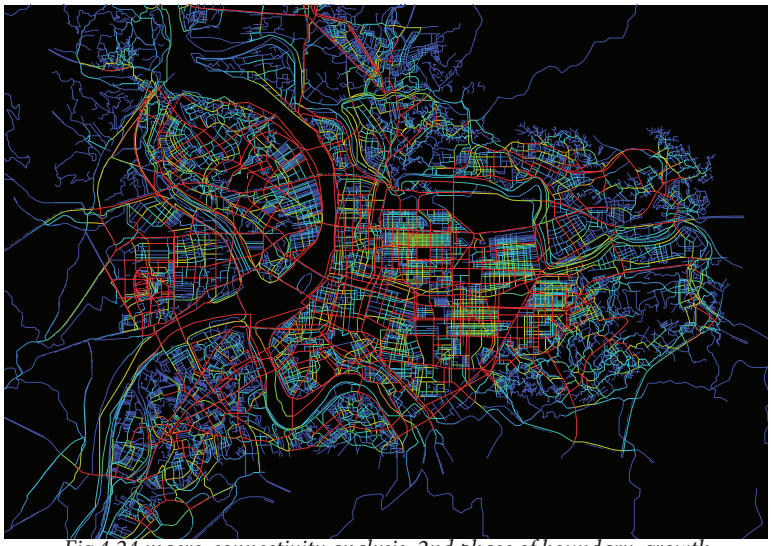


Fig 4:24 macro-connectivity analysis, 2nd phase of boundary growth

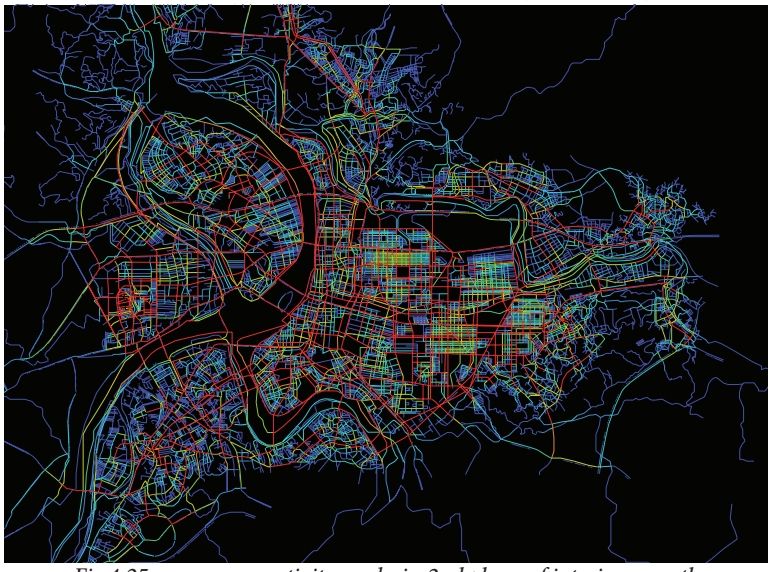


Fig 4:25 macro-connectivity analysis, 2nd phase of interior growth

area. Additionally on a macro-scale new growth has increased the connectivity of the low density areas adjacent to the studied area.
Though the sprawl in area 4 is not as prolific in its spread the seen in external attractor mappings, despite this the diversity in the configuration of the new growth is similar to that seen in exterior mappings with the advantage that there are remaining spaces between the new growth, the terrain restrictors and the existing urban fabric.

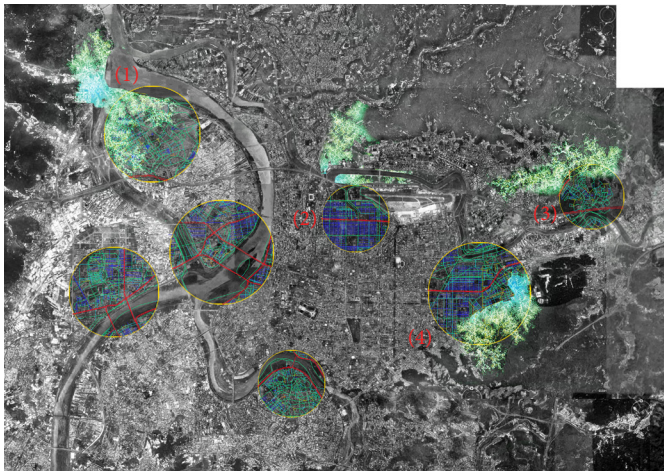


Fig 4:26 1st phase of composite growth

Results.

The mappings indicate that no one approach out of the three, the positioning of interior, boundary and exterior attractors is appropriate for encouraging the growth of sprawl in every circumstance. Each approach can be appropriate when applied in the correct circumstance.

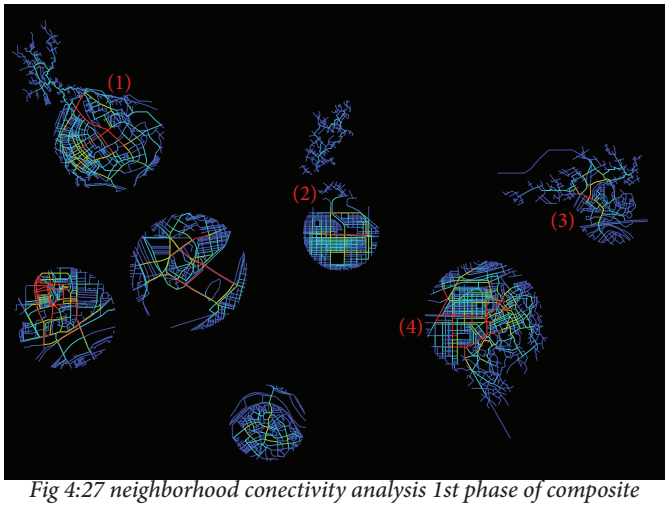


Fig 4:27 neighborhood conectivity analysis 1st phase of composite growth

Area 1: The best results for this area have been achieved through the use of external attractors, this may be due to the fact that the area is already densely populated. The densely populated areas don't have enough available failing space to be successfully reconfigured through interior or boundary attractors. The external attractor win out by providing greater connectivity on the macro-scale, greater growth to the exterior of the established urban fabric, this more expansive sprawl creates new connections between the existing areas of sprawl. If the attractors applied are diverse in there functionality the diversity within the new growth could provide a suitable platform from which a new centre of power could evolve.

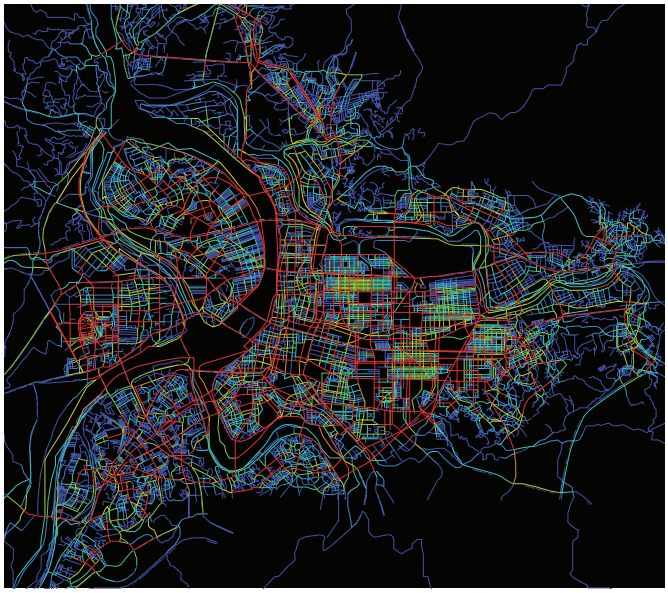


Fig 4:28 macro-connectivity analysis 1st phase of composite growth

Area 2: The positioning of boundary attractors in this area has provided the best results, creating strong links between existing areas of urban sprawl, improving connectivity on a macro-scale. Although the positioning of external attractors encourages greater sprawl and as a result greater connectivity within the existing sprawl, the spread saturates the majority of the available land which

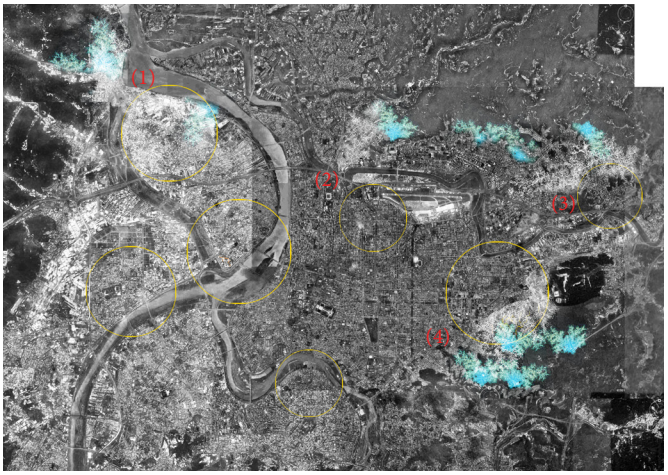


Fig 4:29 2nd phase of composite growth

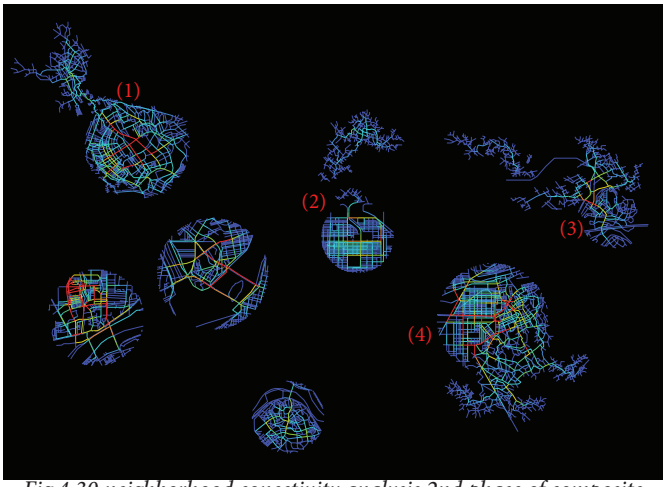


Fig 4:30 neighborhood conectivity analysis 2nd phase of composite growth

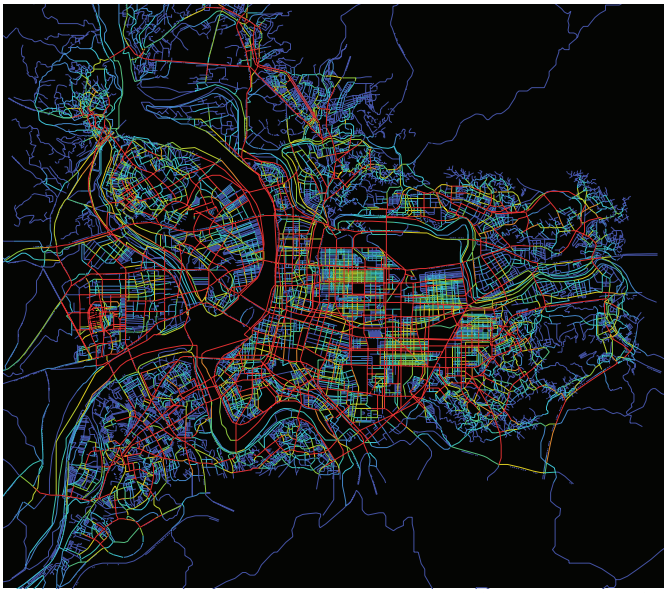


Fig 4:31 macro-connectivity analysis 2nd phase of composite growth

could and so may not provide the same amount of flexibility, required in later phases of growth.

Area 3: Due to the topological restraints both external and internal attractor have been proved to be inappropriate in this area. Internal attractors creates too much connectivity within the low density context and external attractors don't encourage the prolific sprawl seen in other areas as a result of the restrictive terrain. The boundary attractors are most successful in this area, improving connectivity appropriately to the density of surrounding context. Another advantage of the application of boundary attractors in areas 2 and 3 is that new growth is stimulated in areas that are not directly associated with the attractor, this can be attributed to improvements in connectivity across the region and the areas proximity to multiple attractors.

Area 4: External attractors catalysed the most prolific and diverse sprawl forming greatest connections with the existing infrastructure. When compared to the effects of interior attractors, which have similar ranges of diversity and connectivity, it is evident that external attractors create a sprawl that saturates the available land and in doing so restricts adaption in future phases of growth.

Conclusion.

50% of the worlds population currently lives within urban centers and, in developing countries such as China, the mass migration of the population from the rural to the urban is set to continue. The sprawling of the established urban core is an unavoidable result of the massive influx in the population which should be encouraged to grow in a suitable manner rather than combatted. If we understand that urban sprawl in itself is neither good nor bad, but that there are healthy and unhealthy types of sprawl we can develop tools for growing sprawl with diverse and adaptable configurations.

Through the comparison of urban and biological ecologies an understanding that diversity and flexibility are the key factors in securing a stable platform for future growth. Diversity is essential within sprawl, for if an area is reliant upon a single typology which fails in time, the whole area becomes defunct. Through the alternation of the typology used as an attractor in any region we can ensure that the subsequent sprawl is diverse and resilient to future changes.

Wth the use of GIS we can gain an understanding of the factors stimulating and inhibiting the growth of sprawl in any region of the world. GIS also provides information about the existing context which, when combined spacial analysis is used to identify problem areas where intervention is required. With the information gained from GIS we can predict future phases of growth, in response to new stimuli, using cellular automata. Once the growth predicted by cellular automata is integrated into the existing context we can assess the value any intervention on multiple scales.

The Taipei case study illustrates that the extent, configuration and diversity of new sprawl can be manipulated through the strategic placement attractors: internal attractors work best in scenarios where there is space to reconfigure the existing fabric, or where slow compact growth is required; external attractors are most effective in areas where the existing fabric is already saturated, new sprawl creates new connections between the existing fabric and increases connectivity on the macro scale.

The Taipei case study focusing upon shepherding the growth of sprawl. Advanced cellular automata will be able to give an insight into the metabolism and reconfiguration of the existing fabric in conjunction with the additional sprawl to the exterior.

The technique developed is to be used in stimulating the growth of diverse, flexible sprawl with the intention of providing a platform from which new centers of power can evolve. The emergence of new centers of power will develop the city into poly-centric metropolis.

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