ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

OPTIMIZATION IN SPATIAL PLANNING FROM GENERATIVE DESIGN APPROACH: THE APPLICATION FOR GÖKTÜRK, ISTANBUL

M.Sc. THESIS

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<u>İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ</u>

ÜRETKEN TASARIM YAKLAŞIMIYLA MEKANSAL PLANLAMADA OPTİMİZASYON: GÖKTÜRK, İSTANBUL UYGULAMASI

YÜKSEK LİSANS TEZİ

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Merve Deniz TAK, a M.Sc. student of İTU Graduate School student ID 502191886, successfully defended the thesis/dissertation entitled "Optimization in Spatial Planning from Generative Design Approach: the Application for Göktürk, Istanbul", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures

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To my family,

FOREWORD

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June 2023 Merve Deniz TAK

TABLE OF CONTENTS

Page

ABBREVIATIONS

AI	**:** Artificial Intelligence
DMOEA	**:** Dynamic multi objective evolutionary algorithm
FAR	**:** Floor Area Ratio
GIS	**:** Geographic Information Systems
Ha	**:** Hectar
ML	**:** Machine Learning
MOGA	**:** Multiple Objective Genetic Algorithm
NPGA	**:** Niched Pareto Genetic Algorithm
NSGA	**:** Non-dominated Sorting Genetic Algorithm
PAES	**:** Pareto Archived Evolution Strategy
PESA	**:** Pareto Envelope-Based Selection Algorithm
RDGA	**:** Rank-Density Based Genetic Algorithm
SPEA	**:** Strength Pareto Evolutionary Algorithm
VEGA	**:** Vector Evaluated Genetic Algorithms.
VBGA	**:** Weight-Based Genetic Algorithm

LIST OF TABLES

Page

LIST OF FIGURES

Page

ÜRETKEN TASARIM YAKLAŞIMIYLA MEKANSAL PLANLAMADA OPTİMİZASYON: GÖKTÜRK, İSTANBUL UYGULAMASI

ÖZET

Kentler, günümüzde sürekli artan nüfus ve özellikle hızlı sanayileşme dönemi ile birlikte pek çok zorlukla karşı karşıya kalmaktadır. Sürekli ve hızla değişen, öngörülemez, pek çok farklı sistemi etkileyen ve sistemden etkilenen kentlerin ihtiyaçlarına çözüm üretebilmek, mekansal planlama sürecinin yeniden ele alınmasını tetiklemiştir. Geçmişten günümüze, mekansal planlama süreçleri çok değişmese de bu süreçlerin ele alınış biçimleri ve yaklaşımlar değişkenlik göstermiştir. Geleneksel planlama yaklaşımı terk edilerek sistem yaklaşımına yerini bırakmıştır. Bu yaklaşım da şehir plancılarınının mekansal planlama sürecini bütünüyle eksiksiz tamamlası konusunda zorlamıştır. Mekansal plancı (Şehir Plancısı) planlama sürecinin hızlı değişen ve karmaşık bir sistem olan kente hızlı cevap verme ihtiyacı sebebi ile seçenek üretme aşamasını atlanmakta, genellikle tek bir sonuç üzerinden karar vermektedir.

Karmaşık kent sisteminin doğası gereği hızla değişen problemlerine, hızlı çözümler sunabilmek yalnızca insan gücü ile neredeyse imkansızdır. Günümüzde teknolojik gelişmeler sonucu, coğrafi bilgi sistemleri, yapay zekâ, hesaplamalı tasarım gibi yeni teknoloji araçları sayesinde mekansal plancının çok aktörlü, kaotik süreci yönetmesi daha kolay hale gelmekte, bu araçlar planlama sürecinin pek çok aşamasında karar vericiye seçenekler sunarak yardımcı olmaktadır. Bu tezde, özellikle Türk planlama sisteminde varolan ancak hızlı mekansal plan üretimi için gözardı edilen senaryo oluşturma ve seçenek üretme aşamalarında mekansal plancılara bir karar destek çerçevesi sunulması amaçlanmıştır. Bu çerçeve, karar vericilerin hızlı ve verimli bir şekilde kentteki öngörülemeyen ve hızla değişen karmaşıklığı yönetmelerine olanak sağlamayı hedeflemektedir.

Bu çalışma kapsamında, bilgisayar destekli tasarımın alt başlıklarından biri olan üretken tasarım çalışmanın ana yaklaşımı olarak kullanılmıştır. Üretken tasarım, karar vericinin çıktı ürüne odaklanmayıp, sürecin tamamını oluşturabilmekte, çıktı olarak beklenen alınmadığında süreç içerisinde değişiklikler yaparak çok hızlı bir şekilde istenilene ulaştırmaktadır. Bu özelliği sayesinde şehir plancısının planlama sürecinin en başına dönüp zaman kaybetmesini engellemektedir ve şehir plancısı son ürünü üreten kişi değil, süreci yöneten bir lidere dönüşmektedir. Bu özellikler sayesinde hızlı değişen kompleks kent sisteminin isteklerine, uzun geleneksel planlama sürecin içinde çok hızlı şekilde cevap verilebilmekte, zaman ve maliyet kazancı sağlamaktadır. Hızlı şekilde cevap verebilmesinin yanında, üretken tasarım çok kısa zamanda insan gücünün hâkim olabileceğinden çok daha fazla olası çözümler üretebilmekte ve bu olasılıklar arasından ideal seçimleri karar vericiye tanıtabilmektedir.

Geleneksel planlama süreçlerinin uzun ve zorlu oluşu, süreç içerisinde seçenek üretimi aşamasının genellikle göz ardı edilerek tek seçenek üretilip karar verilmesi şeklinde gerçekleşmektedir. Üretken tasarım ise bir karar destek aracı olarak alternatif üretimi aşamasını kolay bir şekilde gerçekleştirmekte, optimizasyon sayesinde şehir plancısına

karar verme sürecinde kolaylık sağlamaktadır. Bunun yanında, seçim için olasılıkların optimizasyonu, üretken tasarımı diğer hesaplamalı tasarım araçlarından ayırmaktadır. Optimizasyon yöntemi ile olabildiğince ideale yakın olasılıklar tespit edilerek seçim süreci şehir plancısı için kolaylaşmaktadır. Optimizasyon süreçlerinde, çözüm olarak hedefin minimizasyonu ya da maksimizasyonu söz konusudur, problemin yapısı ve gerekliliğine göre bu optimizasyon süreci tek amaçlı ya da çok amaçlı olarak gerçekleşmektedir. Tek amaçlı optimizasyon problemlerinde “en iyi” tek sonuç ortaya çıkarken, çok amaçlı optimizasyon problemleri çoklu hedeflerin doğası gereği tek bir sonuç üretememekte, bir yeterince iyiler kümesi oluşturmaktadır. Kentin kaotik yapısı da birçok hedefi beraberinde getirmekte, bu sebeple ideale ulaşamamakta ve çözümler yeterince iyiler kümesini (pareto optimal küme) oluşturmaktadır. Çok amaçlı optimizasyonun ürettiği bu küme, diğerleri içerisinde baskın gelen çözümlerin oluşturduğu pareto cepheyi oluşturmakta ve şehir plancısı binlerce çözüm içerisinden pareto cephe ile istenilene en uygun çözümleri filtreleyebilmektedir. Bugün birçok çok amaçlı optimizasyon yöntemi bulunmaktadır ve baskınlık şekli bu yöntemlerle değişkenlik göstermektedir. Bu çalışmada ise, genetik algoritma temelli bir çok amaçlı optimizasyon algoritması olan NSGA-2 (non-sorted genetic algorithm 2) alternatiflerin seçimi aşamasında kullanılmıştır. Yapay zekâ algoritması olan bu algoritma, diğer bir karar destek aracı olan üretken tasarım ile birleşerek, şehir plancısı için yeni bir karar destek çerçevesini oluşturmuştur. Günümüzde üretken tasarım ve optimizasyon ile mimarlık, kentsel tasarım ölçeğinde çalışmalar yapılmaktayken kent bütünü ölçeğinde yapılan çalışmalar kısıtlı kalmaktadır. Bu tez ile, şehir planlama ölçeğinde bu araçların potansiyel kullanım şekillerine dair bir öngörü oluşturulması ve yeni çalışmalar için profesyonellere neler yapılabileceğine dair ipuçları verilmesi amaçlanmıştır.

Tezin çalışma alanı olarak, İstanbul Merkezi İş Alanı’na bağlanan yol ile hızla talebin yükseldiği, hem kırsal özellikler taşıyan, hem de kapalı site yerleşimlerinin hızla arttığı bir alan olan Göktürk Mahallesi seçilmiştir. İstanbul’un Eyüpsultan İlçesi’nin bir mahallesi olan Göktürk, Merkezi İş Alanı’na bağlayan yol ile talep görmekteyken, özellikle 1990’lı yıllarda öncü proje olarak gelişen Kemer Country Sitesi’nin inşası ile bu talepler ivmelenmiştir, ancak, kentteki donatı alanları bu artan taleplere eş zamanlı olarak karşılık verememiştir. İlk bakışta, donatıların alan yeterliliği sağlamakta gibi görünse de bu alanlar siteler içerisinde kalan özel mülklerde bulunması sebebiyle kentte adil bir dağılım ile yerleşmemektedir. Site içerisinde sağlanan yeşil alanlar, eğitim alanları, sosyo-kültürel alanlar yalnızca mülk sahiplerinin kullanımına tahsisliyken, genellikle orta gelir grubunun bulunduğu parsel tabanlı yerleşmelerde donatı alanları yetersiz kalmaktadır. Covid 19 ile birlikte artan, sağlıksız kentsel alanlardan uzaklaşmak isteyenlerin tercihi olan Göktürk, bu nüfusa açık yeşil alanları, donatı alanlarını karşılayamama tehlikesi altındadır. Alan için ilk olarak yapılan 2003 tarihli 1/1000 ve 1/5000 ölçekli planlarının ardından 2013, 2015, 2019, 2022’de çeşitli revizyonlar, ilave planlar yapılmış ancak çoğu iptal edilmiş ya da değiştirilmiştir.görülmektedir ki, mevcut durumda hızla, doğrusal olmayan bir şekilde değişen bu karmaşık alanın ihtiyaçlarına çözüm üretiminde geleneksel planlama süreci yetişememektedir. Sahip olduğu bu karmaşıklık sebebiyle seçilen Göktürk’ün tez kapsamında öncelikle ihtiyaçları analiz edilmiş ve ardından bu ihtiyaçlar çerçevesinde potansiyel çözümlerin üretemi için bir araç geliştirilmiştir.

İlk aşamada, Göktürk’ün ihtiyaçları iki kısımda incelenmiştir. Birinci kısımda 2041 yılı için İller Bankası yöntemi kullanılarak nüfus projeksiyonu yapılmış ve mevcut arazi kullanımının hiç değişmediği kabul edilerek 2041 yılında donatı alanlarının

Mekansal Planlar Yapım Yönetmeliği'nde(2014) belirtilen minimum alan ve erişilebilirlik gereklilikleri açısından ne kadar yeterli olduğu analiz edilmiştir. Ancak yönetmelikte, erişilebilirlik sınırı için belirtilen çember kuralının, gerçek dünyanın gerekliliklerini karşılamaması sebebiyle, erişilebilen parsel hesapları A*search algoritması kullanılarak, mevcut yol dokusu üzerinden en kısa yol hesaplaması ile yapılmıştır. Analizler sonucunda anaokulu, ilkokul, ortaokul, lise, sağlık alanı, sosyo-kültürel alan ve dini alanların hepsinin alan büyüklüğü olarak standartların altında kaldığı tespit edilmiştir. Yeşil alanlar incelendiğinde, alanda Kemer Country Sitesi içinde bulunan bir golf sahası mevcuttur, ancak bu alan özel alandır ve Mekansal Planlar Yapım Yönetmeliği'nde belirtildiği üzere golf sahaları spor alanı sınıfında olduğu için yeşil alan statüsünde sayılmamıştır. Sonuç olarak, kent içindeki yeşil alanlar da standartların tanımladığı sınırların altındadır. Bahsedilen donatı alanlarında ise, yapılan erişilebilirlik analizi sonucunda yalnızca liseler (%98,9) neredeyse alanın tamamında erişilebilir durumda, liselerden sonra en yüksek erişilebilirliğe sahip kullanım %70 ile ortaokullardadır. Dini alanlar ise %17,5 ile en az erişilebilir kullanımladır. İkinci kısımda aynı analizler, Göktürk için yapılan planların projeksiyon nüfusu için (101366), plan kararları üzerinden uygulanmıştır. 2003, 2015 ve 2022 plan kararlarında tanımlanmış lise alanı bulunmamakta, tanımlı ilkokul ve ortaokul alanları standartların altında kalmaktadır. Ancak, planda "özel eğitim alanı" isimli bir alan tanımlanmıştır, mevcut arazi kullanımı da incelendiğinde, bu kullanımların özel eğitim alanında sağlanacağı öngörülmektedir. Analiz sonucunda, mevcut arazi kullanımında olduğu gibi, plan kararlarında da hiçbir donatı alanı, alan yeterliliğini sağlayamadığı tesip edilmiştir. Erişilebilirlik analizi incelendiğinde, yine hiçbir donatı alanı alanda ideal erişilebilirliği sağlayamamaktadır, en az erişilebilen donatı %3,7 ile anaokullarıdır. En yüksek erişilebilirliğe sahip donatı alanı ise %83,97 ile ortaokullardır. Sonuç olarak, yapılan analizler Göktürk'ün hem mevcut durumda hem plan kararlarında ideal durumdan çok uzakta olduğu göstermiştir, bu sebeple ikinci aşamada standartların belirttiği ideal duruma yaklaşmak amaçlanmıştır.

Çalışmanın ikinci aşamasında, şehir plancısının Göktürk için karar verme sürecine bir destek olarak öncelikle 3 temel senaryo belirlenmiştir. İlk senaryoda Göktürk'ün plan kararlarında bulunan eksiklikleri tamamlamak, ikinci senaryoda mevcut arazi kullanımının eksikliklerini projeksiyon nüfusa göre tamamlamak, üçüncü senaryoda ise alanın potansiyelini anlayabilmek adına "hiç alan kararı olmasaydı, yalnız parsel ve yol düzeni kullanılarak nasıl bir arazi kullanımı ortaya çıkardı?" sorusunun cevabı aranmıştır. Bu üç senaryonun algoritması Rhinoceros programının Grasshopper eklentisinde oluşturulmuş, ilave donatı sayısı ve donatı alanlarının erişebildiği konut parseli sayısının maksimizasyonu, optimizasyonun amacı olarak belirlenmiştir. Bu amaç için anaokulu, ilkokul, ortaokul, lise, çocuk oyun alanı, sağlık alanı ve dini alanlar için belirlenen sınırlar içinde rastgele parsel seçimi parametrik olarak optimizasyona tanıtılmış, parsellerin yer seçimi optimize edilmiştir. Bu optimizasyon süreci, Grasshopper'da çok amaçlı optimizasyon robotu olan Wallacei (Makki et al., 2018) eklentisi aracılığıyla gerçekleşmiştir. Anoaokulu, ilkokul, ortaokul, lise, çocuk oyun alanı, sağlık alanı ve dini alan için ideal alan büyüklüğü ile farkın minimize edilmesi ve erişilen parsel sayısının maksimize edilmesi olarak toplamda 12-14 adet amaç tanımlanmıştır (mevcut arazi kullanımında lise erişilebilirlik kriterlerini neredeyse sağladığı için analiz dışı bırakılmıştır). Her bir senaryo için 5000 adet alternatif üretilmiş, bunlar içerisinden her 12-14 amaç için en iyi çözüm ve tüm amaçların aynı seviyede optimize olduğu çözüm seçilmiş, karar verme aşaması için karar vericiye sunulmuştur.

Yapılan çalışma sonucunda, bu çerçeve sayesinde, tek bir alan için, çok kısa zamanda 2835 tanesi pareto cephesinde bulunan, 15000 adet alternatif üretilmiş, bu alternatifler eniyileme araçları ile karar vericinin ihtiyaçlara göre uygun alternatifi seçmesi için elekten geçirilmiştir, 43 adet çözüm tez kapsamında incelenmiştir. Amaç ve gen sayısının fazlalığı sebebi ile pareto cephesindeki çözüm sayısı beklenilenin çok üstünde çıkmıştır. Gelecek çalışmalarda pareto kümesinin daha iyi yönetilebilmesi için amaçlar ağırlıklandırılarak problem tek amaçlı optimizasyona çevirilmesi ya da amaç sayısının azaltılması önerilmektedir.

Sonuç olarak, bu çalışma ile şehir plancısı geleneksel planlama sürecinde yeni karar destek araçlarını kullanarak, son ürünü birebir tasarlayan kişi değil, planlama sürecinin kendisini kontrol eden kişi haline gelmektedir. Dolayısıyla, bu araç ile çok hızlı değişen, kaotik, çok aktörlü kentlerin ihtiyaçlarına hızlı ve etkin çözümler üretilebilmekte, şehir plancısının sürece hakimiyeti artmaktadır. Burada şehir plancısı ihtiyaç duyduğu durumda standartları ve sınırları tekrar gözden geçirip, yol dokusu, mülkiyet durumu vb. diğer parametreleri sürece kolayca sokarak süreci tekrar kurgulayabilmekte, farklı alanlar için bu model algoritmaya alanın tanıtılması ile kolayca uygulanabilmektedir. Gelecek çalışmalarda bu model alanın gerekliliklerine özgü standartların oluşturulabilmesi için de bir potansiyel taşımaktadır.

OPTIMIZATION IN SPATIAL PLANNING FROM GENERATIVE DESIGN APPROACH: THE APPLICATION FOR GÖKTÜRK, ISTANBUL

SUMMARY

Cities, especially with the rapid industrialization period, are facing many problems today. Generating solutions to the needs of cities that are constantly and rapidly changing, unpredictable, influenced by many different systems, and affecting them is challenging for urban planners. While providing fast solutions to the rapidly changing problems of the complex urban system is almost impossible with human power alone, today, with the help of new technological tools such as geographic information systems, artificial intelligence, and computational design, it has become easier for urban planners to manage this chaotic process. These tools assist decision-makers in various stages of the planning process. Still, due to the need to respond quickly to the rapidly changing city, alternative creation stage is often skipped in a long traditional planning process, and decisions are usually made based on a single outcome. Therefore, this thesis aims to provide a framework that facilitates scenario development and alternative selection, often skipped in traditional planning. In addition, this framework aims to enable decision-makers to manage the unpredictable and rapidly changing complexity efficiently.

In this study, generative design, one of the subheadings of computational design, was used as the primary work tool. It was selected due to it can focus on the entire process rather than the output product, and it can quickly reach the desired result by making changes within the process when the expected output is not achieved. This feature prevents the urban planner from returning to the planning process's beginning and wasting time. Instead, the urban planner becomes a manager of the whole process rather than the person producing the final product. With these features, the rapidly changing needs of the complex urban system can be responded to quickly within the long conventional planning process, providing time and cost savings. In addition to reacting rapidly, generative design can generate far more alternatives in a short period than human power can handle and helps urban planners make ideal choices among these possibilities.

Göktürk neighbourhood of Eyüpsultan county, Istanbul, was selected to implement this tool as the case study area. Göktürk, where demand is increasing rapidly, has both gated communities and rural characteristics. Although, at first, it may seem that the gated communities in this area provide adequate facilities, they do not respond to the needs of the rapidly changing city due to the privatization of services. Therefore, Göktürk, chosen due to its complexity, was first analyzed to see how much it meets the demands. In the first part, a population projection was made for the year 2041, and it was investigated how adequate it will be in 2041, assuming the current land use has not changed at all. The Spatial Plan Legislation (2014) determines the minimum area requirements and walking distances that were also the limit for the analysis. The results show that all the kindergarten, primary school, secondary school, high school, health areas, sociocultural areas and worship areas are below the standards regarding the area size. In addition, accessibility ratios are also lower than the ideal, except for high

school (98,9%). For the second part, the same analyses were made for plan decisions, and it was seen that land use decisions don't meet the standards like in the current situation.

In the second part of the case study, three basic scenarios were primarily determined to support the urban planner's decision-making process for Göktürk. The first scenario was made to fill the gaps in the current situation; the second was also made to fill the gaps between the ideal situation and plan decisions; the third scenario was made to see the area's full potential, assuming that there was no defined land-use decision before. For this purpose, the Rhino Grasshopper plug-in was used as a generative design interface to create the design algorithm. For the algorithm, random parcel selection within limits determined for kindergarten, primary school, secondary school, high school, children's playground, health area and religious areas were parametrically introduced. These aims defined 14 fitness objectives of the algorithm as minimizing the difference between ideal and existing area size and maximizing the accessible housing parcels for kindergarten, primary school, secondary school, high school, children's playground, health area and religious area. In total, 15000 solutions were generated and after, these solutions were optimized by using NSGA-2(non-sorted genetic algorithm 2), 2835 of them located on the Pareto front. Finally, to narrow the selection space, the fittest solutions of each fitness objective and the average fitness rank = 0 of each scenario were represented to the decision-maker.

To sum up, this new framework attempted to adapt to the rapidly changing city's need and control the planning process with multiple alternatives within the limits of Turkish planning standards for areal adequacy and accessibility. It is believed that this tool will start further discussions about a collaboration of urban planning and new technological decision support tools, their implementation at municipal levels, and their contributions to participation in decision-making by representing the alternatives and helping to select via optimizing.

1. INTRODUCTION

Decision-making is becoming increasingly difficult in the increasing complexity of cities. Therefore, many professionals have developed various decision-making tools as a solution. In this thesis, after understanding the complexity of the city, it was investigated how alternative generation and decision-making processes can be made effective by using generative design and multi-objective optimization as one of the decision-making tools. In the first chapter of the thesis, the scope of the literature on this problem and the motivation for the study was introduced, the research questions were identified, followed by a brief description of the workflow of the methodology.

1.1 Background & Motivation

Cities are developed structures formed due to different, multiple relationships between the natural, built and social environments within them. These natural, built and social environments evolve with the migration from rural to cities, and many urban problems emerge. Cities were tried to be understood with a need for a holistic perspective, which system theory attempts to provide to solve these problems. Firstly, although the definition of cities as systems arising from the hierarchical relationship of many sub-systems with each other was made at first, this definition was incomplete in solving the problems of the city (Batty & Marshall, 2012; Sengupta, 2017; Lom & Pribyl, 2021). Therefore, this concept was developed, and cities were defined as "complex systems". Complex cities -which consist of many different systems, are affected by their creator and then influence them- are called open, chaotic, unpredictable, non-hierarchical, complex (Jacobs,1961), and nonlinear systems, and they show disequilibrium (Batty & Marshall, 2012) due to the complexity they contain. For the problems created by these complex cities, the urban planner has to master the whole process and is expected to manage the entire system. The urban planner, who sets various objectives as a solution to the problems of the space, has produced top-down control mechanisms such as spatial standards to specialize these general objectives for the area (Pissourios, 2014).

Even if these control mechanisms are generally determined, it is costly regarding human capability, time and resources used for identifying, analysing, solving and deciding on the problems. It needs to be specific to the place, which is a complex system. For this reason, various technological tools have been developed for the urban planner/decision-maker to produce fast solutions to complex problems. The most popular tools are Geographic Information Systems, Artificial Intelligence, and Computational Design. Thanks to these tools, decision support tools are created for the urban planner at many stages of the planning process, and the ability to control the complexity of the process is increasing. For example, with Geographic Information Systems, data related to the location can be collected and manipulated according to the purpose, the site can be analysed, potential areas can be identified, and the decision maker can be assisted in planning. In addition, with Artificial Intelligence, problems can be identified, data can be collected and analysed, and even potential solutions can be produced. However, when these tools are used within the scope of a traditional planning approach, satisfactory results cannot be obtained.

Due to cities being fast-changing phenomena with many actors moving in the planning process, today's formal, top-down planning approach cannot fully adapt to these rapid changes. The planning process should be able to catch these rapid changes and produce solutions to these changes rapidly. In addition, many actors enter and exit the process, and many new parameters are included in the system in the search for solutions. It cannot be expected from the urban planner to master these parameters alone without actors. Therefore, in this ever-changing process of searching for answers, the urban planner should not be the one who determines the final form but the one who designs and manages the process (Alexander et al., 1987). Computational design is another technological tool widely used currently to design the urban planning process and produce flexible, resilient solutions against rapid changes in the cities. With the computational design, the process can be defined algorithmically, parameters can be determined, and answers can be produced very quickly by intervening in the part to be revised instead of reproducing the planning process from scratch when minor changes and revisions need to be made. In addition, the computational design enables urban planners to generate and manage vast possibilities, which is impossible using only human power. As a result, computational design is a powerful decision-making tool that can create thousands of solutions for complex systems/cities that change rapidly and unpredictably. But even though it can make thousands of possible solutions, dealing with and selecting from them is another issue for urban planners. Using the generative design, a subset of computational design, these solutions can be eliminated by optimizing in a multi-objective or single-objective way within the scope of the specified problem and getting as close to *the ideal* as possible. In the end, optimized solutions make the selection process easier for urban planners. To apply this theoretical framework practically in a field of complexity, the spatial plan process in Turkey becomes a good case study.

Spatial plan production in Turkey follows a top-down hierarchy and uses spatial standards as a control mechanism in the decision-making process (Pissourios, 2014). These spatial standards contain subjects like building conditions, areal constraints and walking distances, which are defined in "Planned Areas Zoning Regulation" (Planlı Alanlar İmar Yönetmeliği, 2017) and "Spatial Plan Legislation" (Mekansal Planlar Yapım Yönetmeliği, 2014). Within these standards, there exist areal and accessibility limits for service areas, and these limits are determined according to the population. For access to service areas, a circle is drawn from the center of the selected parcel and the accessibility of the service parcel is decided according to this radius circle "Spatial Plan Legislation" (Mekansal Planlar Yapım Yönetmeliği, 2014). However, this classical method does not consider the actual road pattern of the area and these standards are often not achieved as desired due to lack of space and population size. With this complex site selection process, the urban planner, who is expected to control the whole process, cannot produce solutions to the rapidly changing urban problems without any help. However, the use of generative design in alternative generation and decision-making provides many advantages to the decision-maker. With its rapid adaptation to changing conditions, its ability to offer many alternatives to the decision maker, and its ability to find solutions that are closest to the ideal using genetic algorithms (Holland, 1975), generative design, as a decision support tool, has the potential to solve the stated problems more effectively.

1.2 Aim & Structure

It is impossible to solve the problems of cities, which are complex systems, by reaching a single ideal, but the task of the urban planner here is to get as close to the ideal as possible. Without the help of various decision support tools, this will become a very long and challenging process. Especially when the planning process in Turkey is analysed, due to the long decision-making process, the complexity of the city creates different demands even at the planning stage, and the plans cannot catch up with these demands. Furthermore, although the planning standards help the decision-making process by creating decision limits, still, the urban planner is in danger of missing the potentials and constraints of the area due to a large amount of data and the complexity of the city; in addition, since the standards are top-down decisions, site-specific needs are not ideally met within the scope of these standards. With this study, using generative design & multi-objective optimization, an example of reaching the ideal state optimally with minimum effort and time was presented. Furthermore, studies combining urbanism and generative design focus mainly on the urban design scale (Akay, 2019; Lima et al., 2021; Chen et al., 2022), while studies on land-use decisions are limited. This study is aimed to contribute to this gap in the literature.

This study aims to create a framework for reducing time and effort costs and to optimize the decisions to reach the ideal for the decisions of service areas according to the defined limitations and spatial standards. Also, this study aims to create a framework to assist decision makers/urban planners in the scenario generation and alternative selection stages of the planning process in light of the area and accessibility standards specified in the Turkish planning system. This framework enables the decision-maker to manage the city's unpredictable and rapidly changing complexity quickly and as effectively as possible within the limits of service ares' area adequacy and accessibility. In this context, the research aims to improve the decisions taken with traditional methods by optimizing with generative design. In this context, these aims form the research question:

"How can more effective, agile and comprehensive solutions be produced for complex urban systems within the limits of today's traditional planning standards?".

To find the answers, the research question was detailed with three sub-questions:

1. **“Which tools can be used to improve the decision-making process and effectively address the problems that cities face?”** was answered to understand the state of the art of decision-making in urban planning. Through the second question,
2. **“How much can the current situation and plans meet the standards that are defined by traditional Turkish planning methods?”** the current situation in the case area was analysed in terms of the standards used in the Turkish planning system as an assistant to the decision-making process and at the same time as a limitation in the production of space. After, the gaps in land-use decisions were identified. Finally, after getting detailed information about decision-making support tools in urban planning and analysing the area, a hypothesis was made that generative design and multi-objective optimization can significantly contribute to scenario creation and alternative selection stages.
3. This hypothesis created the last question, **“How do generative design and multi-objective optimization enrich the production of space and get closer to the ideal?”.** With the last question, alternatives were generated by using generative design. Due to generating thousands of solutions abilities of generative design, the size of the alternative pool became enormous, which cannot be eliminated by only human power. Therefore, the purpose was to find the ideal above all these possibilities. For evaluating these alternatives and deciding on the final, the algorithm optimized by using multi-objective optimization to reach the “ideal” as much as possible.

These questions generated the structure of the literature review (Figure 1.1)

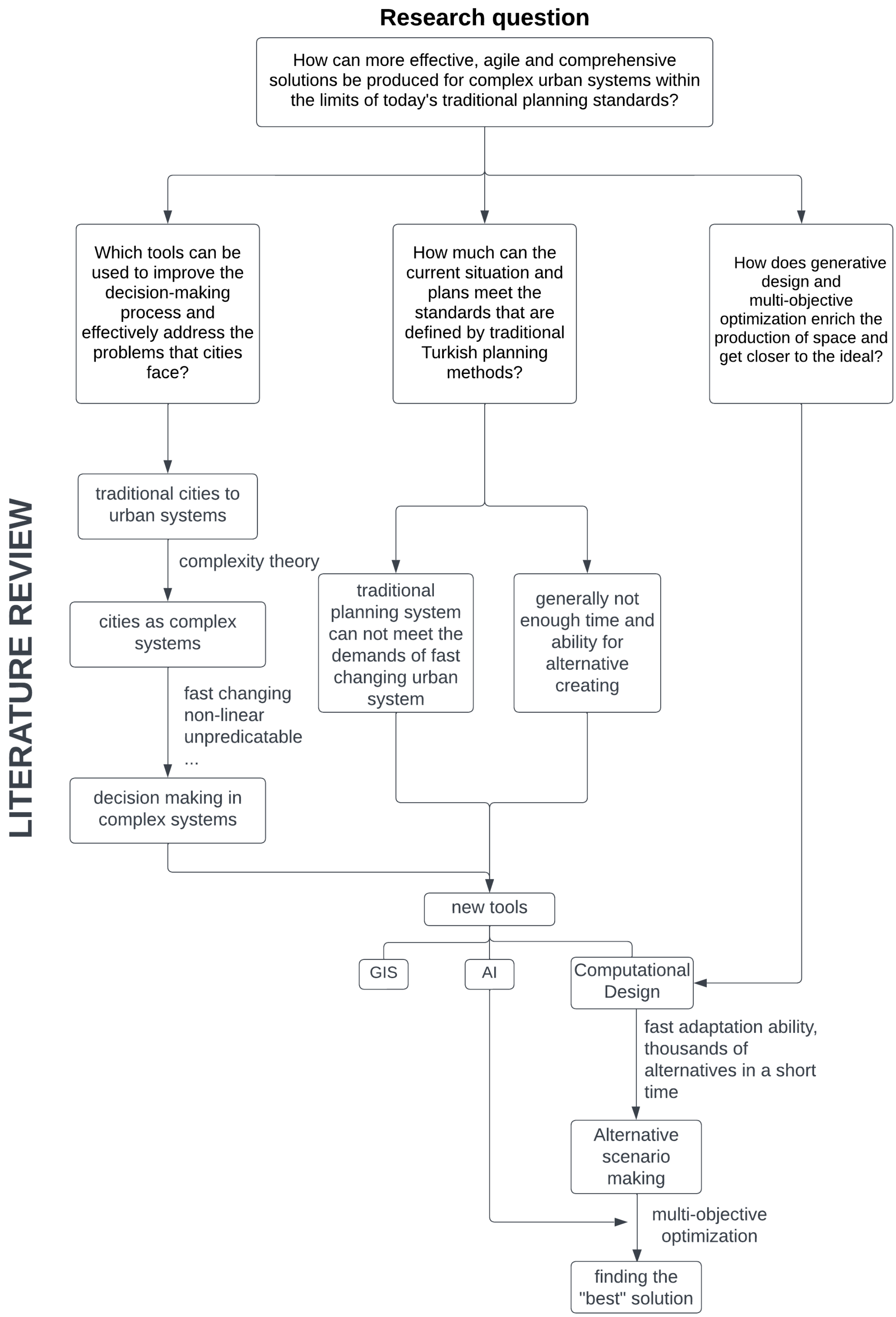

Figure 1.1: Flowchart of literature review

The first question identifies the system theory and complexity in the urban planning view; it was seen that decision-making in complex urban systems is a struggling journey for the urban planner. In addition to this complexity, the decision-making process gets more complicated within the boundaries of traditional urban planning standards, the decision-making process gets harder. To bring a clear vision of this, the second question criticizes the conventional urban planning process due to having a low ability to respond to fast- changing urban problems. These two questions merged in the pursuit of a solution for the challenging decision-making process, and as a result, new decision-making tools were examined as a potential solution. GIS, AI and computational design tools were identified as new tools in urban planning and the potential. It was determined that computational design, with its fast adaptation and fast alternative production abilities, could potentially provide a solution to this complexity, question 3 sought answers on how this tool could address the problem and help to reach the ideal (Figure 1.2). As an output of computational design, the possibility of making choices among numerous alternatives was examined, and how AI, multi-objective optimization could assist urban planners within these numerous alternatives in the decision-making process was explored.

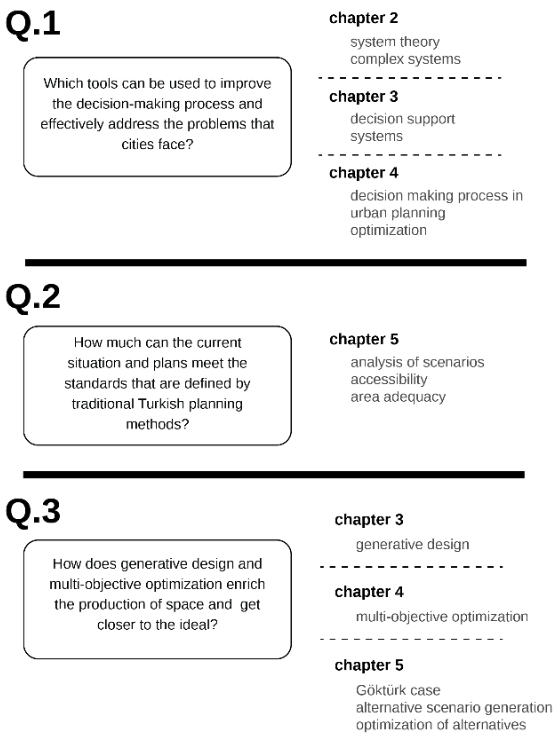

Figure 1.3: Relationship Between Research Questions and Chapters.

1.3 Methodology & Data

To find the answers to the questions mentioned above, firstly, the urban system was discussed within the framework of complex system theory to understand what kind of features a city consists of. After determining that cities need agile and sustainable solutions to catch the needs of these complex systems, new potential tools, which are Geographic Information Systems, Artificial Intelligence and Computational Design, were determined as a way for finding these solutions. After reviewing the theoretical framework of these tools, the computational design was selected as the base tool for this study by using generative design (a subtitle of computational design) with the help of artificial intelligence, creating a fast response framework for the complexity of the city. A highly demanded and complex case area was selected as an experiment area to fulfil this aim. Firstly, its needs according to Turkish Planning standards were identified for the area, and gaps were determined in the scope of areal adequacy and accessibility distances of service areas. The defined accessibility distances in Spatial Plan Legislation (Mekansal Planlar Yapım Yönetmeliği, 2014) are calculated using the radius rule, which is unsuitable for the real world, meaning the complexity. Therefore, to understand the exact needs of the city, accessibility was calculated using the A* search algorithm, which is used for pathfinding in defined road structures. After that, three main scenarios were examined. The first scenario fulfilled the gaps in previous spatial plan decisions made for the areas., the second scenario was created to fill the gaps emerging from the assumption that current land use decisions will continue while the population increases. The third scenario was made for the question, “What kind of land use decisions would emerge from only the current properties and road structure in the light of Turkish spatial planning standards?”. These scenarios were created in Rhinoceros’ plug-in Grasshopper as a generative design implementation interface. After making the scenarios, they were multi-objective optimized using Wallacei (Makki et al., 2018) to reach the ideal as much as possible and represent the “good enough” results according to the defined problem to urban planners/ decision makers. This process aims to help urban planners/decision-makers by creating more powerful alternative creating and decision-making tools. With this tool, defined parameters and constraints can easily change, and different city systems (property structure, road structure) can easily be adapted to a non-linear, fast-changing planning process (Figure 1.3).

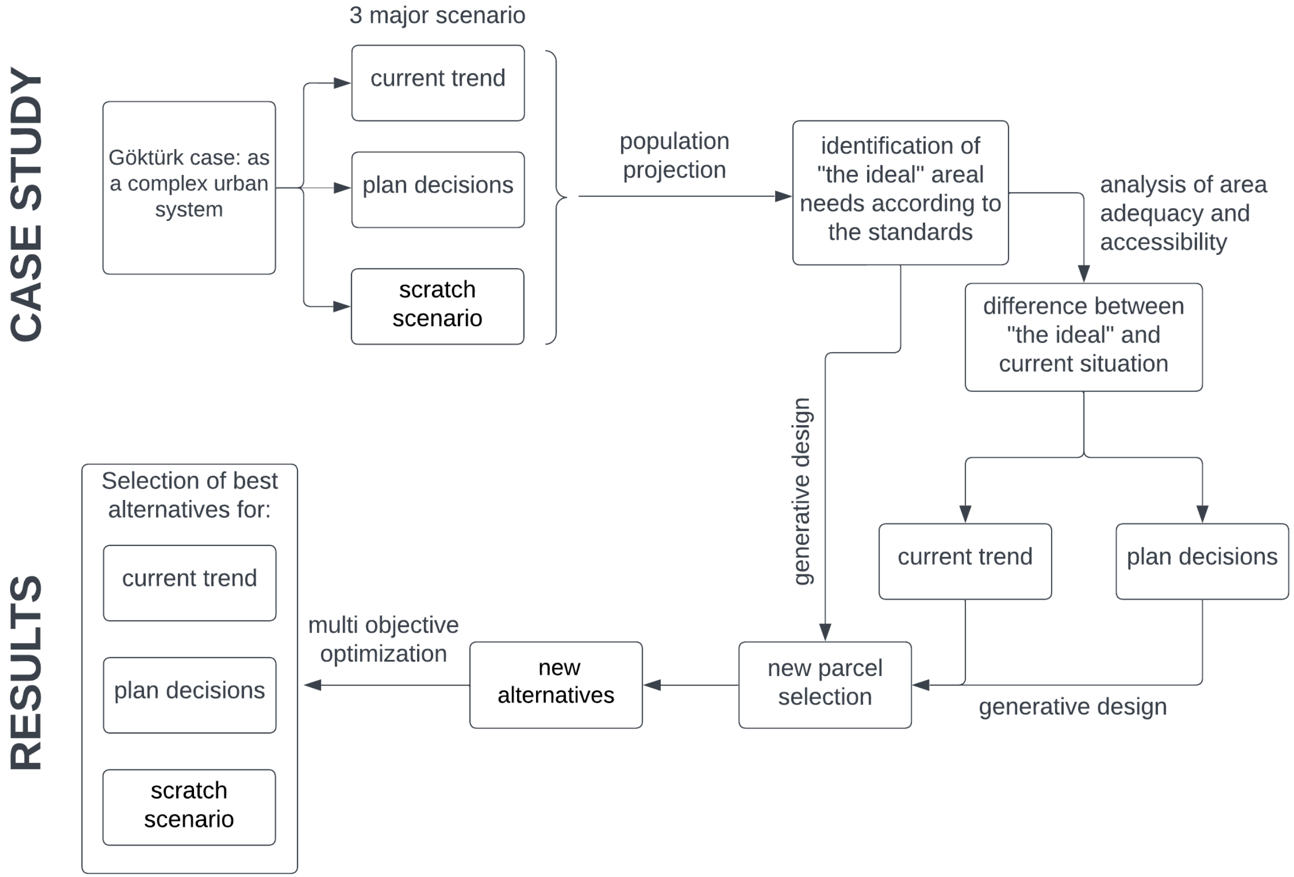

Figure 1.4: Flowchart of Methodology.

2. URBAN SYSTEMS, COMPLEXITY AND PLANNING

First, understanding the city in a more systematic view is essential to find the answers to research questions. Therefore, in this chapter, the evolution of traditional cities to urban systems was identified, and it was seen cities are an open system, which means the urban system affects and is affected by other systems. These interrelations bring the examination of the concept of complexity. Thus, the urban system was discussed in complex system theory and complex system theories' impacts on urban planning were discussed in this chapter.

2.1 From Traditional City to Urban Systems

The great migration from the village to the city with industrialization has brought many problems to the cities. In this process of rapid change, scientists and intellectuals have observed the cities and tried to understand the cities' needs and find solutions. To understand cities' needs, firstly, it is essential to understand what cities are made of. In general, Pumain (2011) states that cities emerge from the interactions of many agents in social, economic, and ecological subjects. Moreover, these interactions' scales can change from a neighbourhood to a country scale. Consequently, many problems arise from these relations. To create solutions, scientists come up with different problem definitions and approaches, and these approaches are released with the developing scientific process and are influenced by multidisciplinary ideas. For example, Brian Mcloughlin stated that the traditional city approach was deterministic, resulting from a straightforward cause-and-effect relationship. However, rapid industrialization and globalization created the need for more flexible ideas for cities (Mcloughlin, 1969). As Mcloughlin stated, one of these ideas can be that *cities are systems*, or in a different saying, cities show systematic existence.

To understand a system, Sengupta defines it simply as an "identifiable organization of a phenomenon" (Sengupta, 2017). These designated organizations have common aims, and they are like subsystems that overlap each other or have hierarchies in them, and the end, these connections create a more extensive system. He also claims that the definition of “system” in urban studies varies due to the subject it analyses, but its hierarchy and relations are common. In another view, Pumain (2011) examines urban systems in 2 levels: the first one is “small cities”, which deals with daily life’s concerns with a small population and the “systems of cities”, which is related to the network of cities at different levels of hierarchy that affects many scales from city to global. Besides, rather than having a “hierarchy”, these two levels show *heterarchy* (Pumain, 2011) because a random agent can affect both levels at any time. In summary, an urban system is made of interrelations of different levels of organisms.

Looking at cities through a systemic view arose in the late 1800s (i.e. Theory of the Location of Industries by Alfred Weber (1929), the principle of hexagonal land allocations for trade and administration by J. Reynaud (1841, as cited in Pumain, 2011) but it became a popular notion in 1950s. Professionals wanted to control the growth that industrialization brings, and they started to examine the economic, social and political subjects in a spatial frame with analytic ways (Sengupta, 2017). However, they produced top-down decisions/plans for more liveable spaces, and the bottom-up choices have not been welcomed during this process, especially in industrial cities, as they would not be controlled and create chaos due to individuals’ intentions and wishes (Batty & Marshall, 2012; Sengupta, 2017). As a more systematic approach than systematically looking at cities, general system theory, developed by biologist Ludwig von Bertalanffy, divides systems into closed -mechanical- and open -living- systems (Von Bertalanffy 1968; Sengupta, 2017). He referred to open systems as non-engineered systems that affect or are affected by other systems, for example, living organisms. On the contrary, closed systems are generally independent of others and do not affect or be affected (*Open and Closed Systems*, n.d.). Consequently, an urban system shows an open system structure, which is affected by its environment and other systems (Sengupta, 2017).

From another perspective, as seen in the top-down planning approach, the idea that cities have linear, hierarchical structures was common. But just like being an open system, scientists have believed that these systems are connected somehow, and they create a new system from these connections. For example, a bicycle road becomes a system with intersections with another system, roadways. And after, these intersections and systems form the whole transportation system of the city (Figure 2.1).

Transportation gathers with other systems like infrastructure, the ecosystem, and the city system emerges there.

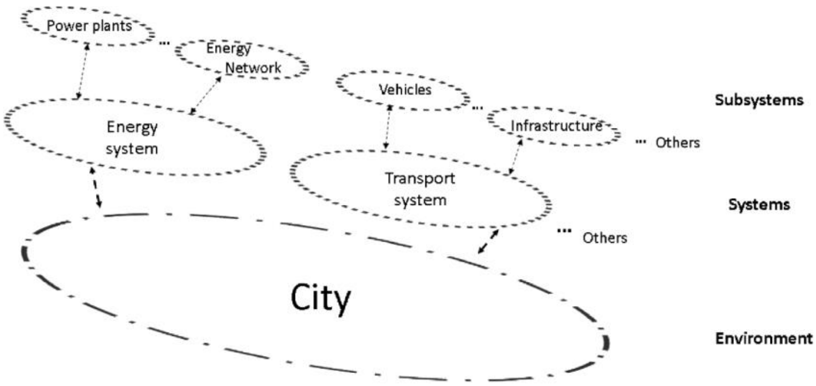

Figure 2.1: The example of a traditional city fitted to the Systems Theory (Lom & Pribyl, 2021).

According to Marshall and Betty (2012), to keep such a system alive and stable, the parts of the system must become resilient and sustainable. Furthermore, in ecological thinking, it is believed that all these functions must be in balance with other functions. For example, Alberti (2008) gives examples of human and ecological functions, and she says that in urban ecology, human and natural processes are interdependent and they must be in balance. If it is not, natural functions will dominate human behaviours, and urban ecosystems will vanish in the end.

A system occurs from its parts or subsystems, but it does not mean that the sum of its features makes it a *whole.* These subsystems must be engaged with the balance to make other system-like elements bind to each other to create a new molecule. Pumain (2011) also names this making process' outputs as *emergent properties* that include new properties which its' components don't have. The urban ecosystem should be read in that way: many systems affect one another, the city system arises from these interactions, and the city systems continue to affect other systems and cities. Even though this process seems in order, this circulation is not usually clear and hierarchic. These interactions are eventually fuzzy and so rapid that they cannot be caught in a general systematic view. Therefore, professionals developed a new system idea, complex systems.

2.2 The Idea of Complexity and Its Theory for Urban Systems

In the 19th century, cities got bigger, systems overlapped, and concerns arose. Many believed cities have a bottom-up complexity and disorder and should be dealt with a top-down management system (Batty & Marshall, 2012). According to scholars, professionals and intellectuals can only know the top-down notion, and only they were allowed to solve the problem. The dynamics of this complexity were being attempted to be understood, but the issues of these systems couldn't be clarified since it wasn't accepted as a complex issue. Later, at the beginning of the 20th century, it was seen that the top-down model couldn’t keep up with these rapid and actual bottom-up developments in cities. Some professionals realized this nonlinearity and rapid changes; accordingly, they have started to bring new definitions of the complex structures of cities.

In 1915, Patrick Geddes -the father of the British town planning system and a biologist- mentioned the organic complexity of cities by using biological analogies like humans as ants or cities as “man-reef” (Batty & Marshall, 2012). In 1961, Jane Jacobs came up with the idea that current instruments in city planning are beneficial because they are top-down approaches against organically growing bottom-up cities (Batty & Marshall, 2012). She defined the process as “seeing the city as a problem of organized complexity, and therefore a problem of the science of life” (Jacobs, 1961). In addition, in 1965, Christopher Alexander published his famous article “A City Is Not A Tree”, and he claimed that cities are “semi-lattice” structures (Figure 2.2) which show multi-layered entangled relations rather than a tree structure (Sengupta, 2017). These explanations opened a new chapter in urban system readings, the complex theory of cities.

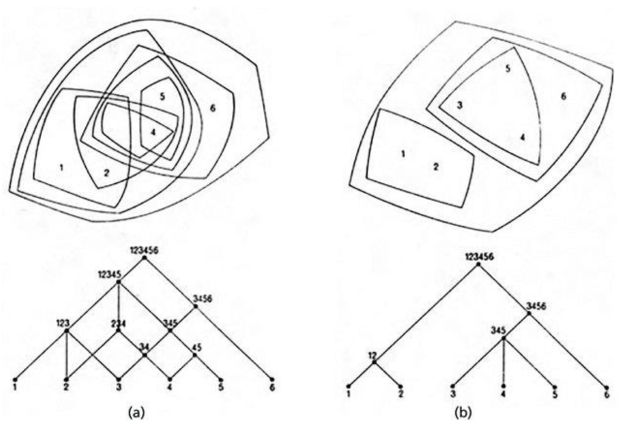

Figure 2.2: Semilattice (a) and Tree Structures (b) (Alexander, 2013).

It is hard to define the start of complexity sciences or theory in literature since it is mentioned unconsciously in many fields and at different times. Complexity theory has many footprints in many disciplines, especially biology, physics, social sciences etc. As Sayama mentioned (2015), complex systems emerged from systems theory, nonlinear dynamics and game theory, and this field is highly related with other subtopics like collective behaviour, networks, evolution & adaptation and pattern formation (Figure 2.3). In the 1970s, systems theory and its linearity, which focused on parts creating the whole, was becoming obsolete. In contrast, the idea that the multiple relationships of components are “complex” for solving problems became popular (Batty & Marshall, 2012).

Moreover, the relations between urban subsystems and others increase the complexity. When Peter Allen first mentioned the complexity theory of cities in 1981, he noted that cities have an ***open, chaotic and bottom-up behaviour*** like natural complex systems (Allen & Sanglier, 1981). Portugali, on the other hand, defines cities as artificial complex systems formed by interactions between agents and, once created, affect those agents (Portugali, 2016). In addition, Sengupta contributes to complex urban systems by demonstrating the importance of system theory, chaos theory, dynamical systems and cybernetics for complex systems (Sengupta,2017). He claims that dynamical systems refer to the constant change in complex systems, chaos theory demonstrates the unpredictability of the complex system, and cybernetics refers to the management, connection and control of the complex system. Lastly, he concluded that cities should be read within these characteristics of complexity. Overall, when looking at cities through complexity theory, it can be said that cities are living organisms with the elements of a complex system like nonlinearity, unpredictability, self-organization and chaos (Batty & Marshall, 2012).

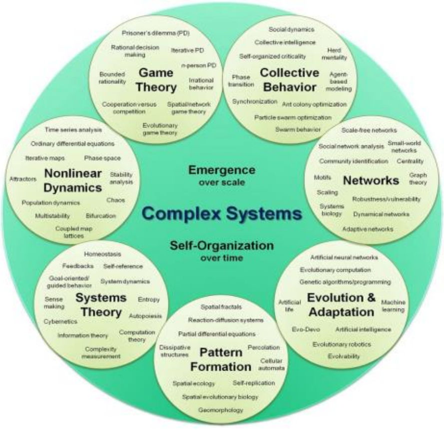

Figure 2.3: Visual organizational map of complex systems (Sayama, 2015).

Although complexity may seem like a complicated issue, according to Marshall (2012), complexity has many benefits, including perceptual richness, functional capacity and synergy. For example, individuals have more psychological satisfaction in complex systems because humans evolved in a complex environment, and a complex urban system feels like their home compared to simple systems. In addition, complex systems show high functional capacity due to their adaptation ability to various situations, and they show the synergy between their components and other systems.

To create results for urban systems' complex problems, it must be identified that complex systems show nonlinearity, are unpredictable, are at the edge of chaos, are self-organised, and are adaptable (Cilliers, 2000; Alberti, 2008). These characteristics require fast and flexible solutions. The multiple parameters of complex systems, which affect the systems bidirectionally, prevent a single good result due to the nature of the problems (Batty & Marshall, 2012; Colander & Kupers, 2014; Crawford, 2016). Humans cannot reach a solution alone in systems with so many inputs. Therefore, human decisions are today supported by computers and technologies. In many stages of the plans produced as a solution to complex urban systems, new technologies help the decision maker as a decision support system to shorten the process and create flexible and resilient solutions.

2.3 Chapter Evaluation

In this chapter, the system theory and complex systems theory were discussed in the urbanism frame, which emerged after rapid industrialization and globalization as an answer to the problems of cities. Firstly, general system theory was implemented in urban studies for looking more systematic view, and it emphasizes that cities are emergent properties from relations of different subsystems in hierarchical order. However, it was stated that cities are open systems that can affect and be affected easily by other subsystems, which means they have heterarchy. This heterarchy brings unpredictability, non-linearity, chaos and dynamism characteristics to the urban system, bringing constant complexity in urban areas. This complexity complicates the planning process due to the continuous and rapid change, and multiple interactions with different agents create various solutions for problems, making the decision-making process challenging for professionals. The next chapter will discuss how and what type of decision support systems can help the urban planner to make the decision-making process more straightforward in this complexity.

3. DECISION SUPPORT SYSTEMS IN URBAN PLANNING

The decision-making process is challenging in complex systems due to the constant change, non-linearity, chaos and multi-agent structure. Moreover, urban planners must deal with all these issues while being aware of all parameters and actors, which is nearly impossible. Therefore, different decision support tools were developed to help the decision-maker by shortening time and cost. In this chapter, general popular decision support tools like GIS, AI and computational design and their contributions to urban planning/decision-making process were discussed; some of them were used as the decision support tool in the context of this thesis.

3.1 Decision-Making in Urban Planning

As mentioned in Chapter 2, cities are complex open systems, changes come up rapidly, and problems arise unpredictably. The urban planner's role here is to catch these changes/issues as much as possible and, after identifying these, create resilient solutions to them. For that, the urban planner has to analyse the city as a system, and to analyse these systems in more detail and to produce effective solutions, the urban planner uses the general urban planning process as a systematic view. The urban planner has to define the problem, analyse all the related parameters, synthesise them, find possible solutions, and decide on one that shows a similar attitude to a general decision-making process. The decision-making process can be explained as reaching an ideal or intended solution to the current situation, and the process can be identified in Figure 3.1 (Sugumaran & Degroote, 2010).

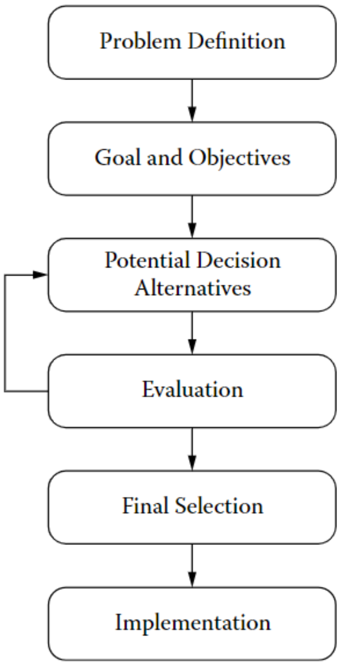

Figure 3.1: Decision-Making Process (Sugumaran & Degroote, 2010).

For the urban planner managing this process from start to finish, the process is challenging, and decision-making is difficult in a complex, chaotic, unpredictable system. Many stakeholders come in and out of the process, while natural and artificial systems influence each other. These dynamics often lead to the fact that no single solution can be found. Therefore, according to Sugumaran & Degroote (2010), the decision-making process gets more complicated with the evaluation stage. It is not expected that all stakeholders can know all functions and data throughout the entire process due to the limitations of human cognitive abilities. Moreover, the alternative generation stage is often skipped due to the time and cost constraints of the planning process and evaluation is made with only one scenario.

At this stage, computer-aided tools are used as a decision support tool to help the decision maker at the various stages of the urban planning process (Sugumaran & Degroote, 2010). Decision support tools have a wide range, from a spreadsheet to real-time simulation tools, and today they are highly beneficial for complex urban system problems (Schindler et al., 2020). More specifically, spatial decision support tools let to store, organize, manipulate and process the knowledge, and they can ease the complexity of the urban system by dealing with multiple agents and possible outcomes.

Spatial decision support tools mainly focused on GIS and spatial modelling approaches in the literature (Schindler et al., 2020; Sugumaran & Degroote, 2010). Today, with GIS, Artificial Intelligence based models, and computational design, new paths are opened to designers, urban planners, and decision-makers and new possibilities are discussed.

3.2 General Digital Support Systems

There exist many different decision support systems in urban planning but in the scope of this thesis, most common ones like GIS, AI and computational design were discussed in this chapter.

3.2.1 Geographic information systems

Geographic Information Systems are computer-based programs that allow for managing and manipulating spatial data for effective decision-making in urban planning (Han & Kim, 2007, 298). In the beginning, traces of GIS can be found in the 19th century with cholera disease mappings or in World War I with photogrammetric techniques (Sugumaran & Degroote, 2010). GIS in computer science emerged in the early 1960s and became commercial in the 1980s (Esri, n.d.). It can be used as a tool and a database management system in urban planning. It allows site selection, land suitability analysis, land use and transport modelling, the identification of planning action areas, and impact assessments ("GIS For Urban Planning | Benefits, Applications, & Tools," n.d.). GIS tools are also used in participatory planning processes and e-governance by fastening the operation and efficient data management. From these application areas, it can be said that GIS usage plays a large part in urban planning. Since GIS works with remote sensing, it gathers spatial data like land use, transportation, and vegetation for urban planners. Using these data, GIS allows for making queries, manipulations, and mapping the area's current situation in the analysing stage. It also helps in modelling and projection by using a predictive model or route calculation with network or overlays analysis to identify suitable areas. Overall, GIS allows making decision support systems spatially related (Sugumaran & Degroote, 2010). GIS tools need the decision-maker to decide which parameters will be used and their weights. Since the decision-makers' intervention is necessary step by step, the planning process slows down in this stage. In the alternative & plan creation process, GIS can help the planner visualise maps and simulate scenarios generated by the decision maker.

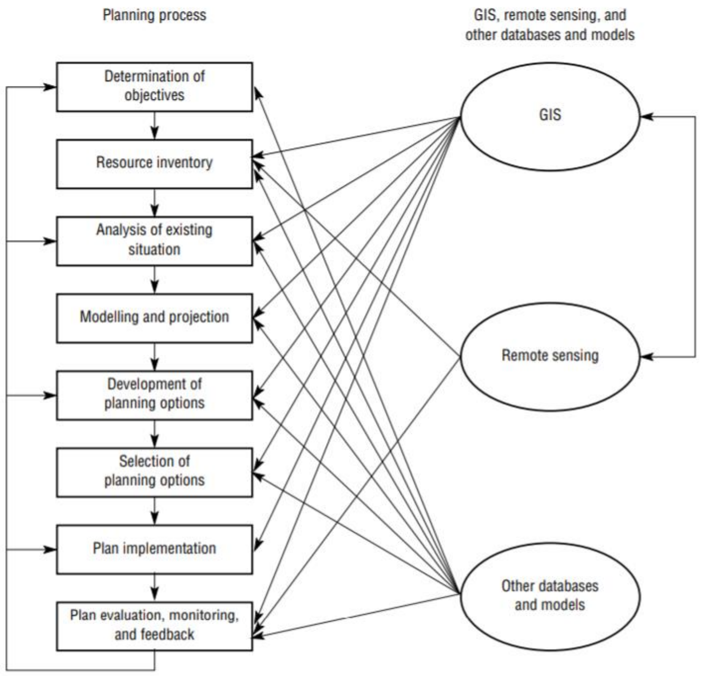

Figure 3.2: GIS and Planning Process (Yeh, 1999).

GIS can help decision-makers with its multicriteria decision-making tools in selecting planning options. In addition, while implementing these plans, GIS helps with environmental impact assessment tools to evaluate possible outputs of plans in the environment (Yeh, 1999). And finally, again, by using remote sensing in GIS, outcomes of plans like land use distribution can be monitored, all these relations were summarized by Yeh (199) in Figure 3.2.

With the development of technology, it can be expected that GIS will merge with other tools daily. As an example of these developments, land use maps can be created to detect road/building structures from satellite imagery thanks to integration with deep learning; instant monitoring and visualization can be done with real-time data like forest fire monitoring (Singh, n.d.). Or GIS can be used for mathematical spatial models like weighted regressions, analytical hierarchy processes etc., and all these developments help decision-makers in the urban planning process by shortening the time, reducing costs, and generating more accurate data & analysis.

3.2.2 Artificial intelligence

Traditional methodologies and databases were used to understand and predict land changes in the past years. They have mostly had top-down and linear approaches for these complex urban systems (Wu & Silva, 2010, 246). The data used could not catch the changes in real life and lagged, and the solutions were shaped dependently by human talent and based on old data. Even though it is still hard to understand this complexity, with the development of AI technologies, it is easier to read and respond to this.

AI is a branch of computer science that combines hardware and software with data-based and knowledge-based processing models to indicate the characteristics of human decision-making with a set of algorithms (Shubhendu & Vijay, 2013, 28). Although AI technology's roots date back to the 1950s, it gained its reputation in the early 20th century. Mainly, AI systems are used for learning, reasoning, perception, problem-solving and language understanding (Bansal, 2021), and they can generate more accessible data management systems by automating, taking and managing data from multiple sources quickly. With this data, it can create more sophisticated statistical data than humans can; besides, AI's learning ability eliminates uncertainty and complexity (Yigitcanlar et al., 2020). AI can also detect system anomalies, like changes in user behaviour patterns and activities (Zhongwen, 2021). It has various uses in many fields, like traffic estimation, smart robot technologies, security, image reading and detection, minimizing human errors in decision-making, etc. The usage of AI in cities created smart city concepts from all these technological developments. And the smartness of a system means *sensing, collecting information, and taking action* from the environment (Atzori et al., 2021). Today, many cities are trying to create smart solutions to reach sustainable, resilient, and efficient cities. In this process, AI technologies' contribution is significant. Yiğitcanlar et al. (2020) have mentioned the most common contributions of AI to smart cities in 3 dimensions: economic, environmental and social. As it mentioned in Table 3.1, AI contributes to the economy by improving productivity, reducing expenses, improving decision- making by analyzing enormous amounts of data, and logically providing conclusions. in a logical manner. In addition, it analyses changes in the environment in real time, reduces energy costs with smart energy and, smart transportation systems, and it helps detect diseases (Yiğitcanlar et al., 2020).

Table 3.1: Different dimensions of smart cities (Yigitcanlar et al., 2020).

Economy Dimension of Smart Cities	Environment Dimension of Smart Cities	Society Dimension of Smart Cities
Enhancing productivity and innovation by automating data management and analysis	Monitoring changes in the environment	Improving health monitoring
Reducing costs and increasing resources through pattern recognition	Using smart energy systems to optimize energy consumption and production	Enhancing health diagnosis outcomes
Supporting decision-making by analysing large volumes of data from multiple sources,	Planning, development, and use of households to reduce energy consumption	Providing autonomous tutoring systems that are highly individualized and adaptive to needs and external changes
Drawing conclusions based on logic, reason and intuition.	Operationalizing smart transport systems	

There can be added more and detailed sub-dimensions to these contributions. For example, AI can understand the changes in user behaviours, detect the potential threats and anomalies in cities and act according to them. For example, ML (machine learning) applications can see the number of vehicles or persons passing, detect traffic congestion areas and optimize traffic light patterns according to them. (Ravindranathan & KP, 2021).

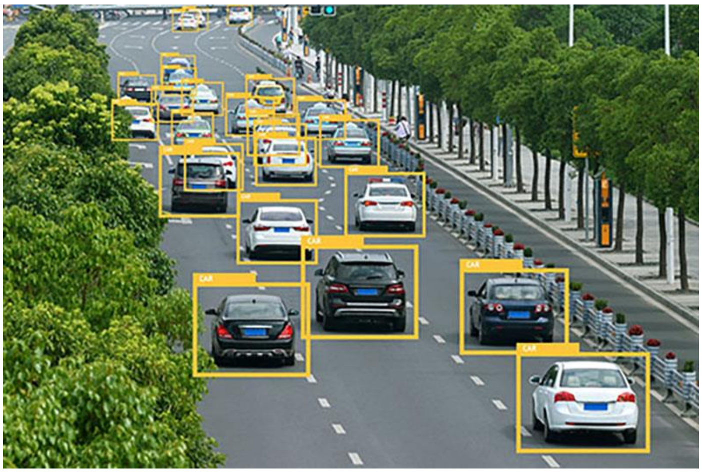

Figure 3.3: ML detects traffic congestion (Ravindranathan & KP, 2021).

Plus, it can automate the management and creation of analyses and make estimations and forecasts, like air quality estimation or population growth. For example, air pollution estimation was made by using traffic data, air characteristics and ground-level pollutants using sensors (Arnaudo et al., 2020). As another example, a neighbourhood's parking capacity can be estimated by satellite images and machine learning techniques (Rentsch, 2019), and traffic congestion can be detected by using ML (Figure 3.3) (Ravindranathan & KP, 2021).

Moreover, AI technologies can optimize designs with the help of generative design tools. Cellular Automata, genetic algorithms, artificial neural networks, and agent-based models are the leading examples of optimization techniques in urban planning. In this study, genetic algorithms were used as an optimization method which was explained in Chapter 4. AI has the ability to problem definition by trend monitoring and anomaly detection. Image reading, collecting and managing data from different sources, and making complex statistical analyses and estimations help in analyzing the process of urban planning. It also helps the decision-maker by forecasting and modelling. In the alternative creation stage, AI helps urban planners by collaborating with generative/parametric design tools. It can define optimized routes in transportation, optimized land allocation according to accessibility etc., and it can help the decision-maker by showing optimized results. In the implementation and feedback stage, AI helps urban planners with real-time data management and fast analysing abilities to observe the environments' reactions to decisions. With the development of these technologies, some believe that AI has lower decision errors than humans, which is valuable for response to urban system's complexity ("AI Can Make Better Clinical Decisions Than Humans: Study," 2021). This assumption is still open to discussion due to ethical concerns and the scope of the studies. Still, in future works, AI's contribution to the decision-making process can be expected to increase significantly.

3.2.3 Computational design

Providing fast and harmonized solutions for today's rapidly changing cities is essential for creating resilient cities. The uncertainty in the plans and the involvement of many actors in the process make the situation more complex. The traditional top-down planning approach currently used has difficulties in solving this complexity. For this reason, it is necessary to produce new planning approaches that are responsive and can adapt to rapidly changing cities. In 'A New Theory of Urban Design', it is stated that design should move away from the traditional schematic "master plan" approach and become a process that evolves with this complex system and that the planner/designer should not be the person who determines the final form, but the person who creates this form and creates the process (Alexander et al., 1987). This means the planner should be the collaborator in the process. As a solution to these needs and problems, in addition to GIS and AI, computational design methods have been developed to help the decision-maker. With the development of computational design, which allows the designer, especially at the creativity stage, the design of the process mentioned by Alexander et al. (1987) has become more manageable, and the ability to control the procedure has increased. Plus, the chance to generate new possibilities faster brought by computational design has led to the creation of experimental opportunities instead of a single design. Computational design methods are essential in coordination with GIS and AI tools. The roots of computational design can be traced to the late ’50s, but commercial usage began in the 80s (Caetano et al., 2020). Even though it started with the computerization of design intent, it evaluated the computation of more surprising, innovative, and emergent outcomes (Verebes, 2014). When Caetano et al. (2020) study is analyzed for computational design methods used as a planning tool, it is seen that concepts such as parametric design, generative design, performance-based design, algorithmic design, evolutionary design, adaptive design, performative design, biomimetic design, dynamic design and kinetic design are the most commonly used methods under the title of computational design. When their frequency of appearance in the literature is analysed, the most frequently repeated concepts are parametric design, generative design, and algorithmic design. Although performance-based design is in the top three, it has recently lost popularity. It is seen that parametric, generative and algorithmic designs are often mixed or nested. Since Caetano et al. (2020) define algorithmic design as a common subset of generative and parametric design, the more inclusive parametric and generative design is analysed in this section.

3.2.3.1 Parametric design

Parametric design, one of the computational design methods, was first defined in the 70s. Some of them see it as a contemporary architecture style in contemporary architectural avant-garde (Schumacher, 2008), but from a broader perspective, it can be said that it is a design approach that relies explicitly on algorithmic thinking. According to Elghandour et al. (2014), it is a code-based design approach that allows for the developing of many design samples without manually recreating the models (Caetano et al., 2020). In parametric design, input parameters are defined, and new designs are generated by evaluating these parameters. It leads planners to develop solutions and options in developing city structures by dealing with physical forms quickly. This fast design ability decreases project costs and time and allows designers to test diverse options of designs/decisions. And these various options are made from free geometries, which are not strict like a square or circle, but more fluid and coherent because of the parametric design's nature. In addition, it enables control the stages of the process, to return to the beginning whenever desired, to minimize errors and to produce flexible solutions for rapidly changing cities to changing situations. Consequently, it is a design suggestion for the complexity of a city.

Adding to all of these, it is also important to mention that parametric design is frequently confused with *parametricism*. While the parametric design is based on the algorithmic design process, parametricism is a design principle, according to Lee (2015).

One of the most iconic examples of parametric urbanism belongs to Zaha Hadid Architecture. One North master plan is a winner of an international competition for the One-North site in Singapore. In 1999, the government launched the economic blueprint for the 21st century (Industry 21) with the vision of a robust global hub in electronics, chemicals, life sciences, engineering, communications and media, logistics, healthcare, education, and business services (Aw, 2005). They wanted to draw attention to the One North area as an inspiration to reach that goal. The area is about 182 hectares and 10 min away from the central business district, where universities, science parks, and hospitals are located. These features make the One-North site attractive and a potential location to achieve the government's development goal. Therefore, the government made an urban design competition to give an identity to this area. Zaha Hadid architecture won the competition in 2001 with its parametric designed master plan. However, the complexity, large amount of data, and multi-layeredness were a struggle to resolve, so the team decided to reach this problem with a procedural method. They set parameters that change area, density, flow, and environmental and formal restraints. This flexibility and ability to existing additional adaptations ensured the coherency and identity of the master plan (PINTO et al., 2013).

Later, the team also worked on parametric urbanism in the Kartal-Pendik master plan and Thames Gateway plan.

3.2.3.2 Generative design

Generative design's evolution started in the 70s, like parametric design. This notion has been buried deep in literature for a while, but in the 21st century, it became popular again in articles and implementations (Caetano et al., 2020). In 1975, Mitchell described the generative system as a device that generates a potential solution to an initial problem. This simple definition includes the general idea of generative design. Years after, in the 21st century, definitions in literature have increased and become more comprehensive. Ficher and Herr (2001) described generative design as a technique in which the designer uses a generating system rather than directly connecting with materials and products during the design process. In addition to that, other definitions were automatically made like space production (Krause, 2003), an evolutionary-based system that designs to meet the performance requirements of problems (Caldas, 2008), an approach that uses algorithmic thinking and rule-based processor "finding solutions to complex problems" (Zee &Vrie, 2008) for generative design. Lastly, some claim that generative design uses AI to create these solutions (Generative Design 101, n.d). Based on all these definitions, it can be said that it is an approach which can generate multiple possible explanations for complex problems. In the literature, the most common generative design approaches are named shape grammar, L-systems, Cellular automata, genetic algorithms, and swarm intelligence (Abdelmohsen, 2013; Caetano et al., 2020)

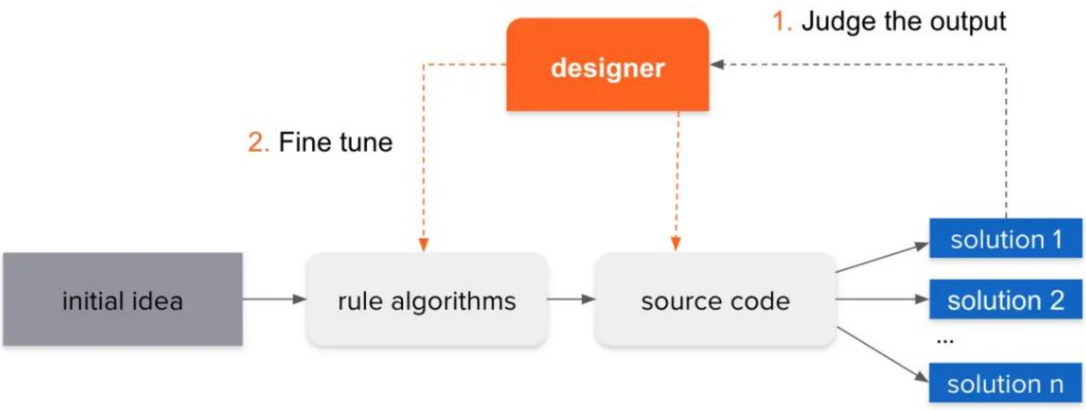

Figure 3.4: Generative Design Process (Generative Design 101, n.d.)

In a typical generative design process, the designer comes up with an initial idea, forms the boundaries and rules, creates source code, gets the various solutions, and decides whether answers are satisfying or not. If the results are not satisfying, the regulations and code can be changed easily according to the needs (Figure 3.4). In addition, the generative design shows optimized solutions for desired objectives. This ability distinguishes generative design from parametric design. Performance-based generative design systems are an excellent example of it. In these systems, the decision-maker defines the problem and sets a goal; then, algorithms try to find the best approximate result to reach this goal (Caetano et al., 2020).

To catch up with the problems and emerging trends resulting from the rapid increase in cities, solutions were sought to solve complex problems quickly. For example, in 2020, Google's parent company's "Sidewalk Labs" introduced their new generative urbanism tool: Delve, which uses Machine Learning and generative design to reveal optimal solutions. They claim that every neighbourhood has different dynamics. Still, they also share some core components like buildings, open spaces, amenities, streets, and energy infrastructure, so they structured their algorithm according to these parameters (Sidewalk Labs, n.d.). After creating the input data (data of these parameters and other dynamics of the area) on the system, depending on the priorities of the case, optimal solutions are created and ranked according to their importance. The highest-ranked solutions are presented to decision-makers, which are real estate developers, designers, municipalities, etc. One of their case studies belongs to Wembley Park, London. Quintain is a real estate company that wants to build a multi-family mix-used development area on North East Lands in Wembley Park, London. Before, the company did some proposals for the site, but daylight access (vertical sky component) and financial cost desires couldn't be achieved. In addition, previous designs created 2400 units, and they believed there could be more. To achieve these aims, Delve team used Machine Learning and generative design. They used building massing, Street structures, and open spaces and constrained themselves with 3.5 acres of open space and maximum height restriction. Forty thousand scenarios were developed to increase the number of housing units, and 24 high-performing possibilities were produced, enabling increased open space, housing units, daylight access, and sun-hours on the ground in 8 weeks (Figure 3.5). They also made a cost-value model and evaluated every potential design's feasibility (cost, value, net profit) with building heights, floor areas and open space parameters (Sidewalk Labs, n.d.) Besides all this process, the project hasn't been finished yet. After the implementation of the project, it will be understood whether it was successful, and its potential problems will be seen.

Priority Outcome	Baseline	Delve	Improvement
Unit Yield	**2,417 units**	**2,612 units**	**+8%**
Average Unit Size	**789 sq ft / unit**	**802 sq ft / unit**	**+2%**
Leasable Residential Area	**1.91M sq ft**	**2.09M sq ft**	**+10%**
Daylight Access	**62%**	**63%**	**+2%**
Sun Hours	**5.9 hours**	**6.1 hours**	**+3%**
Open Space	**7.26 acres**	**8.07 acres**	**+11%**

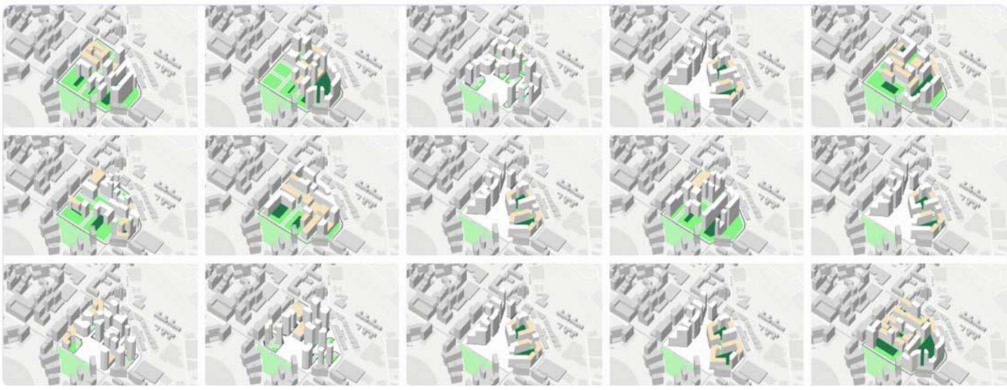

Figure 3.5: Alternative of Quintain Case Study (Sidewalk Labs, n.d.).

To sum up, parametric design can be defined as the coding of a design/problem so that new designs will be created from these parameters by defining parameters and enabling reversibility at the design stage. On the other hand, the generative design optimises the design by manipulating the parameters to select the best design for the problem (Architechtures, n.d.). These approaches exhibit a bottom-up approach by enabling control and intervention at modelling, alternative creating and selecting stages rather than a top-down approach in the planning process. For this reason, it can adapt to complex systems quickly and easily. However, it is unclear how this planning tool will incorporate non-spatial data into the process. In addition, a system such as urban space, which is very complex in terms of physical, social, economic and ecological aspects, may harm the plan's success by limiting the solution to specific parameters in production.

3.3 Chapter Evaluation

In the complexity of the urban system, the process of plan generation and decision-making becomes very long and challenging with human power alone. For this reason, today, computer-aided decision support tools such as GIS, AI and computational design help decision-makers in all process stages. Especially in the alternative scenario-making step, which is usually skipped to catch the change in the rapidly changing city and to react quickly, they help the decision-maker in parts that only human power cannot deal with. And after alternative creation, they also facilitate the alternative selection stage by trying the find ideal, that named *optimization*.

4. ALTERNATIVE SCENARIO CREATION AND DECISION MAKING

Decision-making processes in planning are challenging for the urban planner in the city's complex system. Due to time and resource constraints, decision-making by producing alternatives and selecting from among them is generally not preferred, and only one scenario is usually constructed. However, decision support systems developed to facilitate the urban planner's work have advanced, increasing the decision maker's control of the entire process. For example, as it mentioned in Chapter 3, there exist various tools like GIS, Artificial Intelligence and computational design to facilitate these stages. Thanks to computational design, in particular, today, a decision maker can generate much more alternatives in seconds than they could with human power alone. But, the selection stage from so many options remains challenging for the urban planner. Therefore, various optimization methods are used today to select the best alternative that is suitable for the problem from among the others. This section discusses these optimization notions, such as genetic algorithms and Pareto fronts, and examines examples of their use as decision-support tools in urban planning.

4.1 Optimization

Today, optimization is commonly used in engineering fields like logistics, civil, electrical engineering etc., but its application in other areas -that deals with high complexity- is increasing daily. In a short definition, optimization is the effort to reach the best, desired solution within defined constraints (Küçükkoç, 2020). The best solution can be minimizing or maximizing the goal after optimization understands what is good or bad for the purpose. As mentioned in Goldberg's businessman allegory, the improvement path always results better than before while trying to find the best, which is remarkable in optimization (Goldberg, 1989). This improvement path, that is optimization problem vary according to their objectives, mainly as single-objective or multi-objective. While single-objective optimization maximizes and minimizes the single defined aim of one issue, in multiple-objective optimization, there exists more than one objective, and they usually cross with each other (Sarker & Newton, 2007). On some occasions, these multiple objectives can be merged into a single goal with different approaches like weighting objectives, but many times complexity of the system is high for merging.

Different optimization methods are applied according to the solution size of the problem and the desired solution time. These methods are divided into two general headings as exact and heuristic methods. But in time, meta-heuristic methods as an upper level of heuristics, have been separated from these headings (Martí & Reinelt, 2011). In these titles, exact methods try to find the best solution for a problem. However, these solutions can be very loaded and may need strong hardware capacity, especially in computer science problems. For this reason, unlike exact methods, heuristic methods are used to solve these complex problems. Heuristic methods do not guarantee the best result but produce problem-specific results in a short time, heuristic methods don’t assure the optimum solution, but they are faster than analytic methods (Sarker & Newton, 2007). They are usually designed for a specific problem. For this reason, it improves performance by narrowing the scope by focusing on the features related to the problem's solution. They are predominantly used in operation research and artificial intelligence applications (Rothlauf, 2011). Apart from this, meta-heuristic methods have been developed after heuristics to search for the global optimum. The main difference between heuristic and metaheuristics is that meta-heuristic methods are not problem-specific (Garcia, 2022). However, there is no consensus in the literature on the titles to which these methods belong. For example, evolutionary algorithms are referred to as metaheuristics in Figure 4.1 by Desale et al. (2105), but Kokash (2005) refers to them as heuristics.

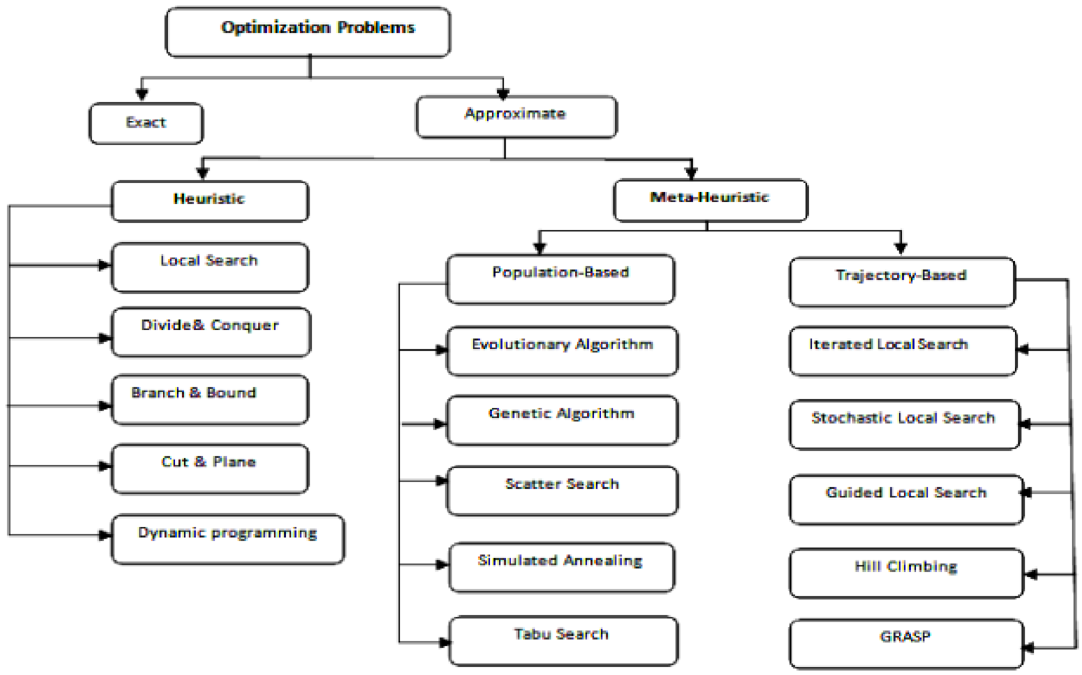

Figure 4.1: Taxonomy of optimization problems (Desale et al.,2105).

In the scope of this thesis, due to the complexity that urban system brings, multi-objective optimization was found suitable for decision making, and the genetic algorithm was applied as the optimization method of this study for finding the ideal.

The genetic algorithm is an evolutionary algorithm method widely used today as a metaheuristic search method. Holland (1975) describes it as an algorithm that tries to solve living complex problems by pretending as a natural selection problem (Holland, 1992). Genetic Algorithms are developed as an imitation of the evolution process in nature and it mimics eliminating weaker species in nature by natural selection so that the stronger ones can pass on their genes to future generations. Powerful genes, just like in nature, undergo some changes during transmission, if these changes are advantageous for the continuation of the species, the species carries these changes to future generations. Irrelevant differences are eliminated (Konak et al., 2006).

A typical genetic algorithm selection process involves the relationships of genes, chromosomes, and population. In here, genes create chromosomes (known as individuals), and chromosomes form individuals by gathering (Figure 4.3). Chromosomes are made of units called genes that define different features of individuals and these individuals compete to be fittest, weak ones are eliminated. Chromosomes(individuals) generate populations, and the most suitable populations are selected according to fitness functions as initial populations for starting point of the algorithm. After selecting initials, crossovers are made randomly or heuristic to create offspring. Some of the offspring mutate to reach the fittest, and after, mutated offspring join the population, and again a new crossover happens. Old populations are removed to create space for new mutations. This process continues until the fittest cannot be made or a defined generation number is reached, and finally, the process terminates (Melanie, 1998; Kumar, 2022). Figure 4.2 represents a general genetic algorithm flowchart that starts from an initial population, selection and continues with crossover and mutations if the first selection is not desired solution (Dastanpour& Ibrahim, 2014).

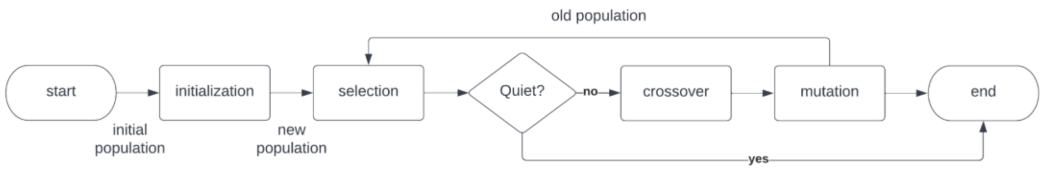

Figure 4.2: Genetic algorithm (Dastanpour& Ibrahim, 2014).

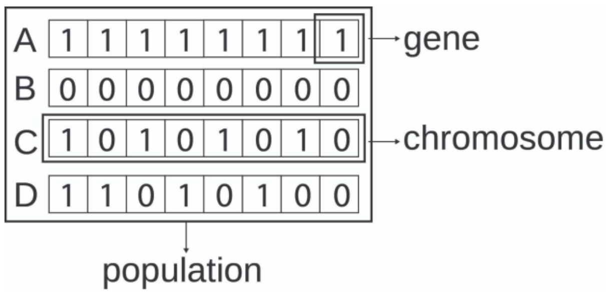

Figure 4.3: Gene, chromosome and population in genetic algorithms (Melanie, 1998).

In general, Multi-objective genetic algorithms do not require any prioritization or ranking by a decision maker, and they are the most popular heuristic approaches in optimization and design. There exist many multi-objective evolutionary algorithms like VEGA (Schaffer, 1985), MOGA (Fonseca & Fleming, 1993), WBGA (Hajela & Lin, 1992), NPGA (Horn et al., 1994), PESA (Corne et al., 2000), PAES (Knowles & Corne, 1999), NSGA (Srivinas & Deb, 1994), NSGA II (Deb et al., 2000), SPEA (Zitzler & Thiele, 1999), SPEA-2 (Zitzler et al., 2001), RDGA (Lu & Yen, 2003) and DMOEA (Yen & Lu, 2003). These 13 are well-known in the literature due to their specialization on fitness assignment procedure, elitism, and diversification strategy

(Konak et al., 2006). In this study, NSGA II has been used as multi-objective optimization, which is the Wallacei plug-in algorithm used for optimization in Grasshopper (see Chapter 5).

NSGA II (Non-dominated Sorting Genetic Algorithm II) is one of the evolutionary algorithms for multi-objective optimization. It was published four years after NSGA (Srivinas & Deb, 1994) as a more effective non-dominated sorting algorithm. Unlike the first version, it excludes the sharing parameters. Furthermore, it has an elitist selection procedure, which means it brings the fittest result from the previous iteration to the next iteration that helps to increase the algorithm's speed (Buck et al., 2019). In addition, NSGA II also tries to keep diversity and brings forward non-dominated solutions (Calle, 2017). Here, non-dominated solutions represent the *Pareto front*, a subset of the Pareto optimal set (Figure 4.4), the main goal of multi-objective optimization (Konak et al., 2006). These pareto sets represent “good enough” solutions, since there is no “one good” solution. Due to the nature of multi-objective optimization problems, In this solution set, some solutions are differentiated from others according to their objectives’ performance success. A solution is named a non-dominated solution if it is no worse than the other solution in any purpose and better than the other solution in at least one objective. After this comparison, non-dominated solutions create *a Pareto front.* To conclude, multi-objective optimization tries to find the Pareto front (Figure 4.4) (Kaya & Fığlalı, 2016).

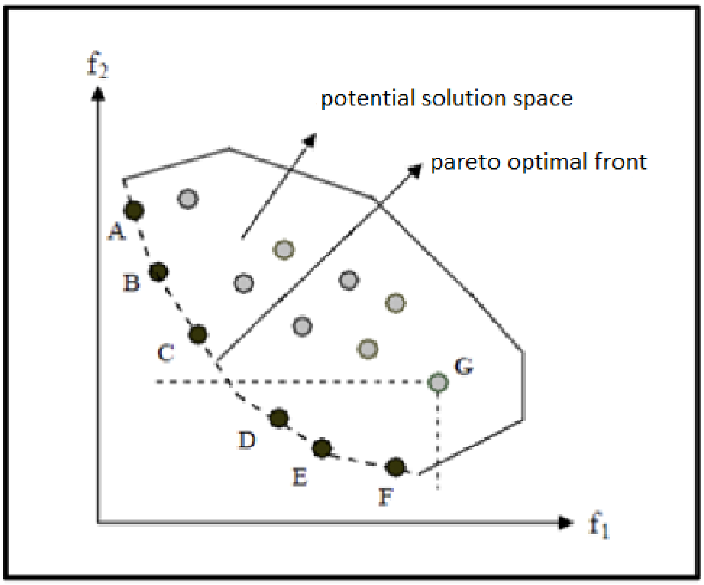

Figure 4.4: Explenation of Pareto Front (Kaya & Fığlalı, 2016).

4.2 State of Art in Optimization in Urban Studies

Even though notions of optimization methods are commonly used in other disciplines like engineering and computer science, few examples of optimization in urban planning / urban design fields still exist. Therefore, in this chapter, three related studies were examined to understand the current state of the art of optimization in urbanism field.

4.3 Algorithmic design control for plot–based urbanism: a model proposal in Turkish spatial planning context

Different solutions should be brought to the city's changing needs, but top-down and static decisions cannot keep up with these changes and harmonised and diverse plans cannot be created. Plot-based urbanism was used as a control tool in this study to create a solution for that and the mediocrity that Turkish urban planning standards make. The study was conducted for the Ibrahim district of Gaziantep, built in the 1970s with a typical zoning plan concept. Four alternative scenarios were created with parametric design, and parameters were determined at the building, parcel, and block scales. Parcel size, floor area ratio, building coverage ratio, setback distance and buildable volume ratio under parcel scale; building height, building front line and creating setback distance under building scale were determined as parameters. Conceptual alternatives are diversified according to the existing parcel layout and the new parcel layout explicitly designed for the area. Scenarios were created as follows:

1. new block formation with current subdivision pattern and current FAR:1.4

2. new block formation with current subdivision pattern and FAR: 2.0

3. new plot layout, generated new urban blocks with current FAR: 1.4

4. new plot layout, generated new urban blocks with FAR: 2.0

After this stage, new footprints were obtained by mixing I, L, and U-shaped building footprints to provide diversification in the area. Height, setback and frontline were added as control parameters. These building islands were optimized in terms of radiation & airflow, and three alternatives were selected for each scenario. Finally, one option was selected, and design codes were produced as plan notes (Akay, 2019), as visualized in Figure 4.5.

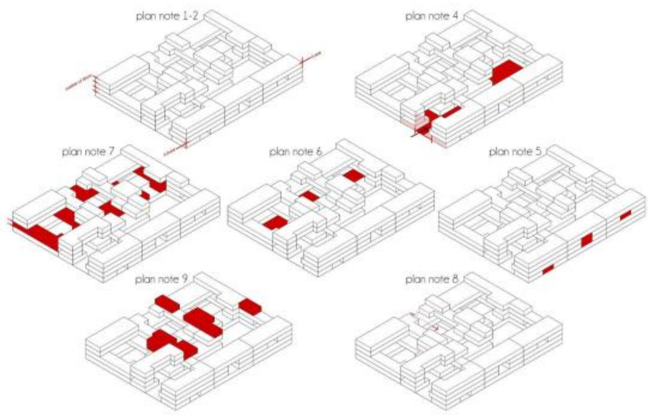

Figure 4.5: An example of design codes for an urban block in the study (Akay, 2019).

4.4 Urban design optimization: generative approaches towards urban fabrics with improved transit accessibility and walkability

This study aimed to explore how to increase urban areas' performance by using different optimization tools and evaluating the production of varying grid structures for good transit accessibility with generative design approaches. For higher transit accessibility, the aim was to decrease automobile usage and increase the walkability of neighbourhoods. At the same time, infrastructure cost was also considered while optimising for higher transit accessibility. For these purposes, a two-step study that includes different complexity levels were examined, which are also at the urban design scale like the first study. In the first step, uniform and non-uniform blocks were generated to achieve a higher physical proximity index (PPI), and nine different single-objective optimization experiments were made to get the best performance of these generated blocks.

Each optimization lasted approximately 8 hours. The parameters of this study were defined as block length (60-200 m), block width (60-200 m), street width (12-20), and grid rotation angle (-90°, 90°). The fitness function of the optimization was identified as the average PPI for all blocks to the central block. Different single-optimization tools were used to evaluate the performance of the first case. The best solution was implemented in step 2 as input.

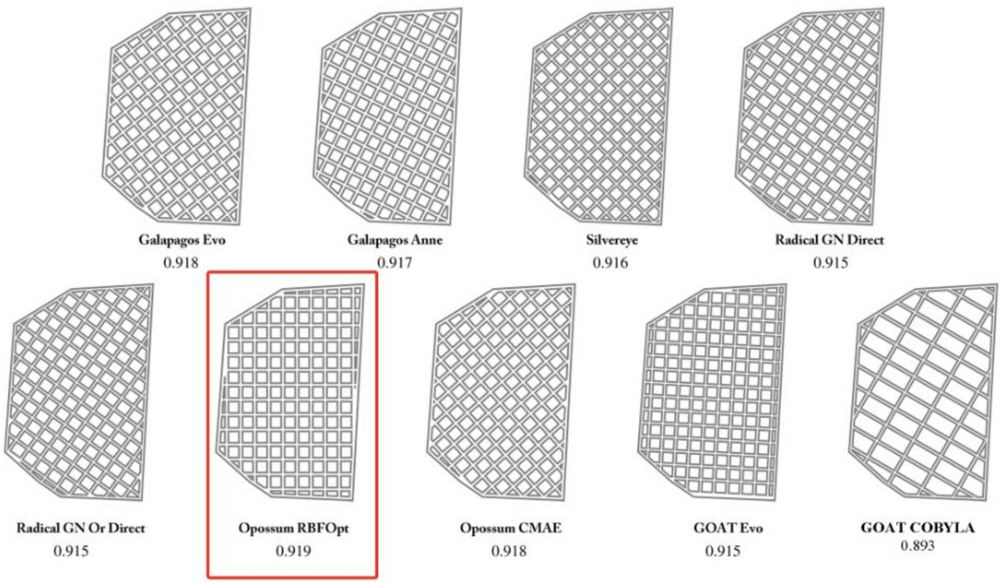

Figure 4.6: Results of the case for generating blocks (Lima et al., 2021).

In step 2, blocks were manipulated with three approaches: subdividing blocks, moving the corners and implementing Voronoi to block design. It was seen that while PPI is increasing, the total area of roads also increases (Figure 4.7), which is not welcomed for cost calculation. Therefore, Wallacei (Makki et al., 2018) plug-in was used as a multi-criteria optimization tool for decreasing cost (total area of roads) while increasing the physical proximity index. (Lima et al., 2021)

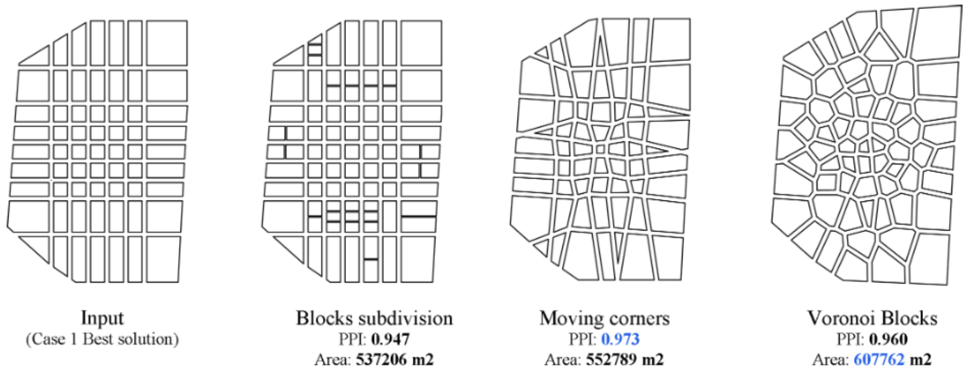

Figure 4.7: Results of case 2 for different fitness functions (Lima et al., 2021).

4.5 Parasite city: retaining the industrial district of Alexandria, Sydney as an integral part of urban regeneration

The study area, Alexandria industrial zone, was defined as a high-density residential area in Sydney's growing population plans. In addition to that, being close to the airport and other residential areas made Alexandria a famous region, and gentrification was started in the area. According to Chen et al., industrial areas struggle to adapt to urban regeneration and are the most vulnerable areas for renewal due to the risk of gentrification (2022). Therefore, in this study, proposals were developed using the evolutionary algorithm to connect the existing industrial area to other residential areas in a "parasitic" manner for minimal demolition and construction, and these were optimized using multi-objective optimization to achieve the ideal. The operation took place in two stages. In the first stage, the current infrastructure and surroundings were analysed to achieve the aim of minimum demolition on the site. In addition, the objectives of this part were identified as ensuring the continuity of existing industrial activity while integrating pedestrian movement to current circulation with new bridges, pedestrian paths, stairs, and parking towers. In stage 2, based on the phenotypes produced in the first stage, the mix used block typologies for the second stage were distributed in the area. The existing industrial roofs were divided into building parcels concerning their proximity to the parking towers, the uses of the neighbouring parcels and building heights. For the first stage, a generation size of 20 and a generation count of 50 were defined in the Wallacei plug-in (Makki et al., 2018). One hundred sixteen solutions were located in Pareto Front. Later, these solutions were K-mean clustered with 9 clusters, 3 of them selected as input for the next stage (Figure 4.8). In the second stage, a generation size of 50 and a generation count 100 were defined, and 172 solutions were located in Pareto Front. These also clustered into 16, and 4 were selected for further analysis. These four solutions were evaluated according to their proximity to other program types and mixed-use typologies (Chen et al., 2022).

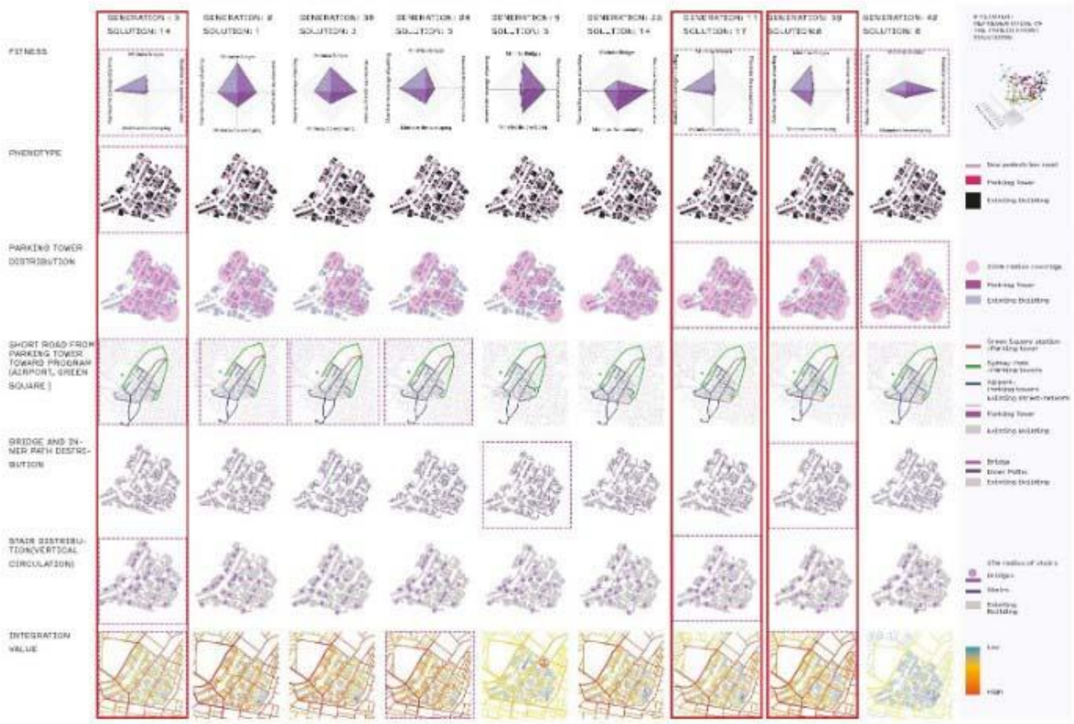

Figure 4.8: Simulation matrix of stage 1 (Chen et al., 2022).

4.6 Chapter Evaluation

In summary, multiple different approaches and methods can be applied according to the research question and type of parameters. While some can give the best result, others do not assure the ideal, but they can provide “good enough” in a shorter time. These optimization methods were discussed in this chapter, and 3 case studies were examined to understand how optimization can be used in urban-related problems. These 3 case studies show brief examples of implementing generative design and optimization tools in decision-making process. In addition to that, they give a hint about optimization searching space and optimization duration according to the complexity of the problem. Apart from these, 3 case studies show that generative design and optimizations in urban-related studies mainly focus on urban design scale. To fill this gap in the literature, this thesis focuses on urban planning scale by using legal boundaries as parameters and focuses on a highly demanded and complex area, Göktürk.

5. ALTERNATIVE SCENARIOS FOR GÖKTÜRK, ISTANBUL

As the case study area, Göktürk was selected, which is a highly demanded neighbourhood of Istanbul today. In terms of land uses, although it seems that green space, education, and socio-cultural areas are provided in this region, which is populated with primarily gated communities, it is believed that fair access couldn't be provided in the region due to the privatization of settlements. High demands of the area, due to being close to the central business district, increased the complexity of this urban area, and decision-making became a laborious process. Therefore, the scope of this chapter is to show how alternatives can be created and selected easily by the decision-maker by using generative design and multi-objective optimization with three major scenarios (Figure5.1). Firstly, the area was analysed to detect deficiencies in the current situation and spatial plan decisions, new alternatives were generated to fill these gaps of area adequacy and accessibility for specific service areas (Figure 5.1), and finally, these alternatives were optimized, and selection space was narrowed to ease the selection stage.

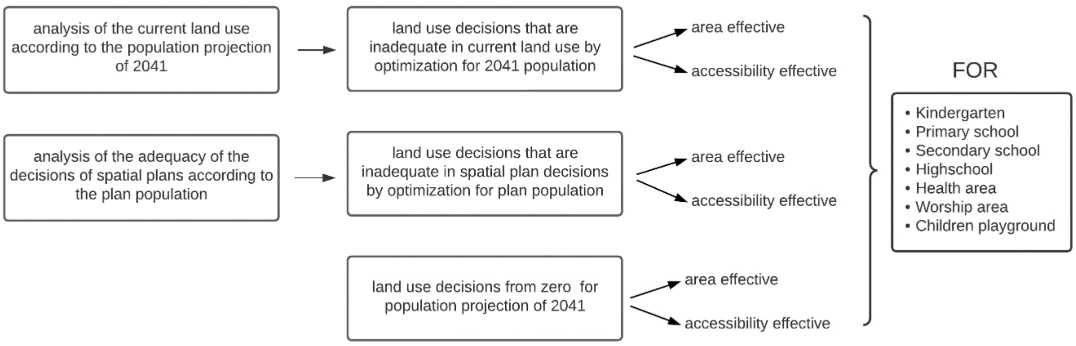

Figure 5.1: Analysis and generation structure of scenarios.

5.1 Prefatory Remarks: Göktürk at a Glance

To understand better the complexity of Göktürk, the development of the area over time was examined, and current situation and spatial plans were identified.

5.1.1 Location and history

Göktürk, which is named as “Göktürk Merkez neighbourhood”, is one of the 28 neighbourhoods of Eyüpsultan County (Figure 5.1). The history of Göktürk goes back to the conquest of Istanbul.

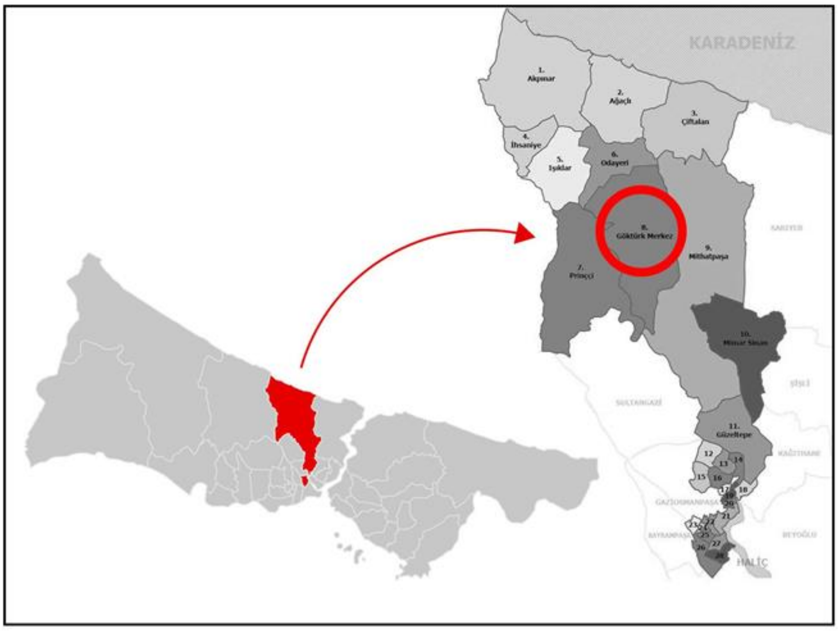

Figure 5.1: Location of Göktürk (Eyüpsultan District Governorship IT Chief, n.d.).

The area had agricultural village characteristics until 1973 with the new road connection between Istanbul’s central business district, Maslak and Göktürk. This road connection and being near forest areas has increased the attractivity of Göktürk. This region, which is close to business areas and far from the fast-metropolitan life, has gotten the attention of the high-income class. In time, thus, the area experienced a rapid transformation. Firstly, the Kemer Country Site, one of the first gated communities in Istanbul, was built in 1990. It was built on a 1200 ha area, 300 ha golf area included, inspired by traditional neighbourhood development and new urbanism movements. Along with Kemer Country, gated communities started to form in Göktürk and created the area's characteristics. Unlike the parcel-based settlements, these sites were “postmodern residential areas with private security” (Çelebi Gürkan & Özaslan, 2019), where municipal services were privatized.

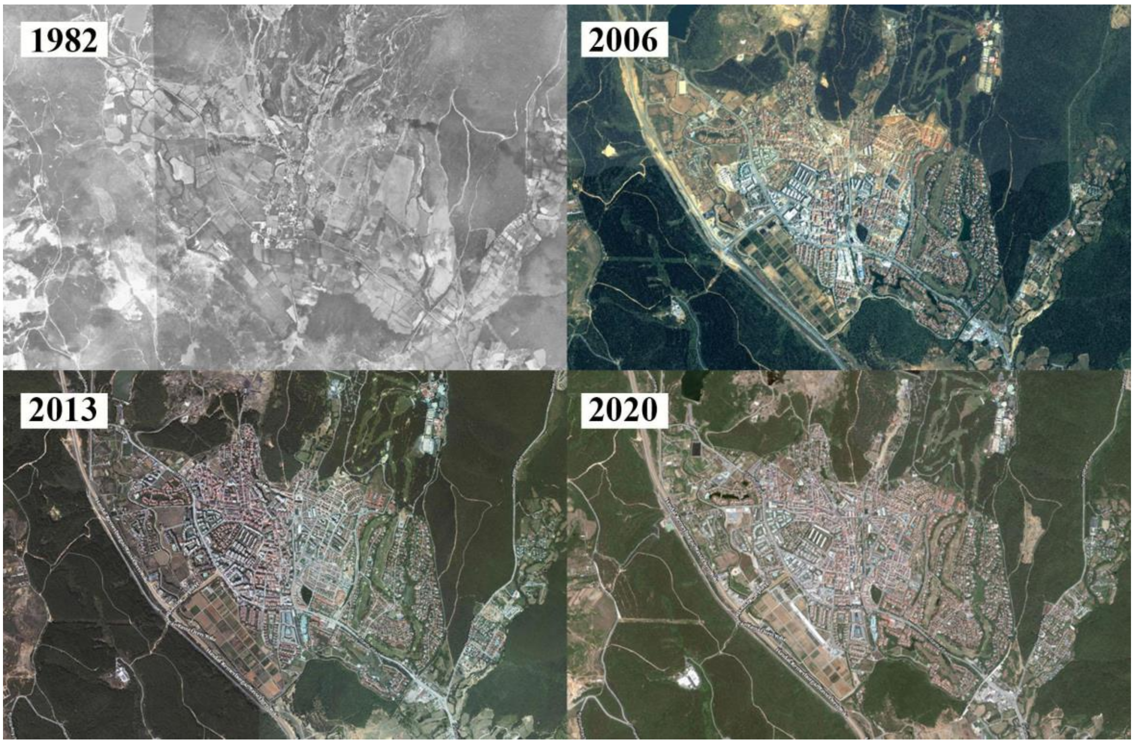

Figure 5.2: Sattelite photos of Göktürk from 1982 to 2020 (Istanbul Metropolitan Municipality, n.d.).

The neighbourhood connects major working areas with D020 Hasdal-Kemerburgaz and Kemerburgaz Cendere roads. On the west side, Istanbul Street connects Göktürk to the Mimar Sinan neighbourhood. The site is located near Gayrettepe - New İstanbul Airport metro line construction. After the opening of this metro line, the increased transportation opportunities to the region will further increase the demands of the area (Figure 5.2).

5.1.2 Current land use

The boundary of the study area was defined as the total boundaries of the 2003 “Göktürk county municipality 1/5000 Zoning Plan” and 2022 “1/1000 Implementation Plan for The Göktürk Neighbourhood Reserve Area Plan” which gated communities exist in the majority of the study area. Consequently, green and public spaces are mainly inside these gated communities (Figure 5.3). Even though it may seem like many green areas are located in the area, these green areas are not open for public usage, which means access to adequate public space is not provided. Therefore, existing open spaces are insufficient for residents except for gated communities and the potential demands.

Figure 5.3: Current Land Use of Study Area.

Table 5.1: Areal distribution of current land use.

Land Use Type	Area (Ha)
residential area	147,46
commercial area	1,49
residential + commercial area	2,79
health area	0,63
mosque	0,79
kindergarten	0,79
primary school	1,46
secondary school	1,52
highschool	1,55
private education centre	0,03
administrative area	0,42
active green area	2,48
passive green area	9,23
cemetery	1,05
sport area	1,05
sociocultural area	0,58
empty area	3,42
in Construction	6,17
agricultural area	0,44
pond and stream	5,04
golf area	15.14

5.1.3 Göktürk in spatial plans

The 2021 population of Göktürk Merkez neighbourhood is 39137 (Turkish Statistical Institute, n.d.). It has been seen that the increase has accelerated, especially after the 1990s (Figure 5.4).

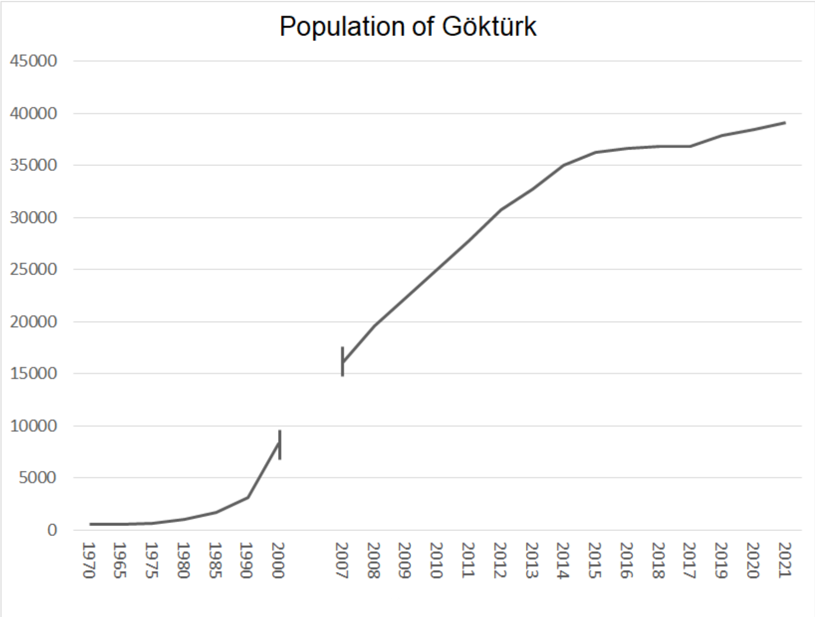

Figure 5.4: Population Between 1970-2021 of Göktürk (Turkish Statistical Institute, n.d.).

Göktürk has a significant potential to meet the housing demands of Istanbul, whose population is increasing rapidly. this potential has brought the need of new decisions, after 2003, many plans were made in 2013, 2015, 2019, and 2022 but most of them were cancelled or revised.

Göktürk's first zoning and implementation plans were made on 19.06.2003 (Figure 5.5) named "Göktürk county municipality 1/5000 Zoning Plan" and "Göktürk County Municipality 1/1000 Implementation Plan". The total plan area was 214.39 Ha with 914.881 m2 residential and 185.642 m2 residential + commercial area. Plan year and projected population were not defined in these plans, but still, most of the area decisions come from them (Table 5.1).

In 2015, "Implementation Plan for a Part of Göktürk Settlement" was made for the outer side of Göktürk. In the plan explanation report, the 2003 "Göktürk County Municipality 1/5000 Zoning Plan" population projection was determined as 98549.

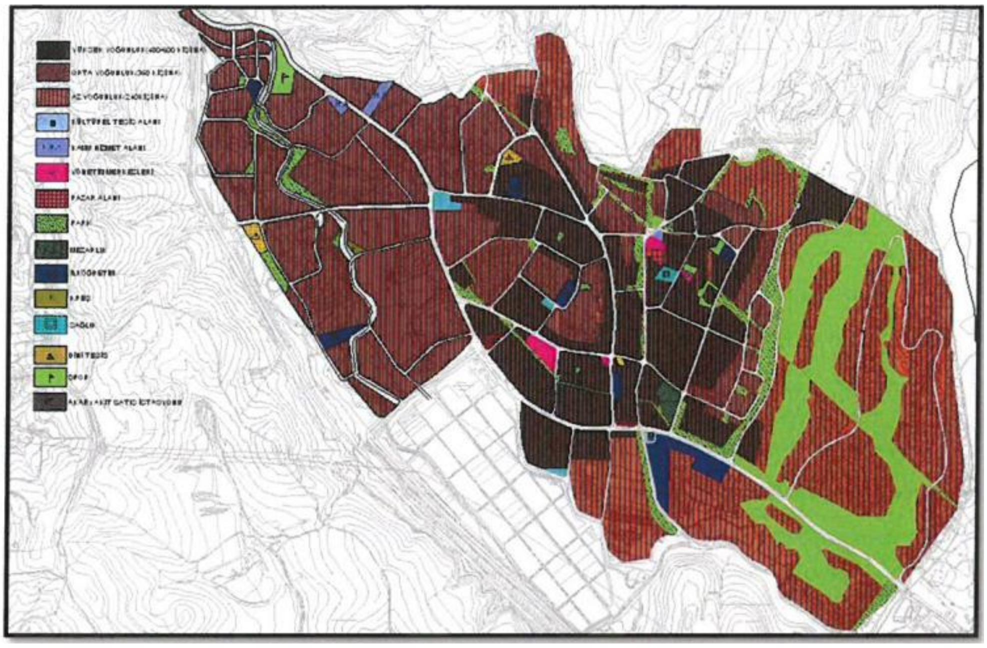

Figure 5.5: Göktürk County Municipality 1/5000 Zoning Plan (2003).

In 2022, "1/1000 Implementation Plan For The Göktürk Neighbourhood Reserve Area" was made for the southern side of Göktürk (Figure 5.6). According to the plan report, a 23.2 ha residential area will be implemented, and the population will be 2817 of added area (Figure 5.6).

Figure 5.6: 1/1000 Implementation Plan for The Göktürk Neighbourhood Reserve Area (2022).

For this study, population projection from plans was calculated as 101366. But, neither "Göktürk county municipality 1/5000 Zoning Plan" and "Göktürk County Municipality 1/1000 Implementation Plan (2003)" nor "1/1000 Implementation Plan for the Göktürk neighbourhood reserve area (2022)" defined the projected plan year in their plan explanation reports. When Göktürk's current population of 39137 is considered, it can be said that an overestimation was made for the settlement in the 2003 plan. But the allowing of the reserve area settlement shows that population growth is still expected in Göktürk, despite the current situation, which is far below the projection estimate of the 2003 plan.

In the scope of this thesis, the projection year is defined as 2041 for the scenarios. For the Göktürk current trend population projection, the "İller Bank Projection Formula" has been used, and a 70685 population has been estimated for 2041 (Table 5.2).

Table 5.2: Population projection of scenarios for 2041.

	2003 plan population	2022 addition plan population	Total projected population
Current trend			70685
Plan decisions	98549	2817	101366

5.2 Analysis of the current situation of scenarios

When looking at cities through system theory, it can be said that planning is a form of cybernetics that uses control devices to fix system errors, according to Mcloughlin (McLoughlin, 1969). In this process, goals are defined to correct these errors in settlements, but since they are too general and not quantitative, spatial standards are used as a tool by forming general goals for specific plan actions. Spatial standards help to see the difference between the desired situation and the current. Besides, they help to shorten the decision-making process by defining limits and starting points (Pissourios, 2014). In addition, spatial standards can provide equal access to public services for everyone as a requirement of democratic rights. From another perspective, even though spatial standards are a powerful tool for fixed urban systems, some planning approaches don't believe in their power. According to the communicative planning approach, standards don't include local actors' preferences; they come from only expert knowledge. Besides, they are not area-based solutions, which restricts the creation of new possible concepts and solutions (Pissourios, 2014).

Spatial standards have been figured as a top-down tool in spatial plans at the beginning of the 20th century due to the search for order after WWII. Today, countries like Hong Kong and Italy use standards as obligatory rules, while federal countries like Germany USA use them for guiding / advising (Pissourios, 2014).

In Turkey, “Planned Areas Zoning Regulation” (Planlı Alanlar İmar Yönetmeliği, 2017) and “Spatial Plan Legislation” (Mekansal Planlar Yapım Yönetmeliği, 2014) establish spatial standards to provide equal and ideal quality of life in planned areas. These regulations are the results of a top-down planning decision and are legally binding. The Planned Areas Zoning Regulation (Planlı Alanlar İmar Yönetmeliği, 2017) explains the construction conditions, such as parcel sizes, pulls, and road widths, while the Spatial Plan Legislation includes the areal standards of the services and the walking distances to some services (Table 5.3). These distances are calculated by creating a range from the radius of the service parcel centre, but this method gives primitive results for complex urban structures. Accessibility cannot be provided only with radius calculation.

Table 5.3: Defined walking distances to service areas (spatial plan legislation, 2014).

Service Type	Walking Distance Radius (m)
Children’s playground	500 m
Open Neighbourhood Sport Area	500 m
1st Stage Health Center Nursery	500 m
Preschool	500 m
Primary School	500 m
Secondary School	1000 m
Highschool	2500 m
Small Size Mosque	250 m
Middle Size Mosque	400 m

The walking distance method defined by the standards is insufficient for creating fast and effective solutions in the urban structure. The accessibility of the field should be examined with its inputs, and decisions should be made according to the actual state. For this reason, in this study, the access of service areas over the existing road structure was calculated by using the A* search algorithm -shortest path finding algorithm-, which is a heuristic approach (Isaac computer science, n.d.), to create a fast and effective solution to the accessibility problem of the complex urban systems. As a result of this analysis, the accessibility of the existing plan and current land use were evaluated. In the next section, alternative site decisions will be developed with the optimum accessibility parameter by using the A* search algorithm.

A* search algorithm is developed as a heuristic version of the Dijkstra algorithm, and it is used for shortest path finding in robotics, video games and many other fields. The heuristic approach helps to find “good enough” solutions quickly, making it suitable for complex problem-solving and working faster than the Dijkstra algorithm (Isaac computer science, n.d.).

The access of housing parcels to service areas was examined based on the existing land use of the Göktürk neighbourhood. This analysis was done with the shortest walk plugin using the A* algorithm via Rhino-Grasshopper visual coding tool. Analysis was made by finding paths between housing parcels’ center projections to road and service parcel centre projections to roads (Figure 5.7). The paths were involved in the analysis as split lines from intersections and projection points of parcel centres and the topography was included in the anlaysis (Figure 5.8).

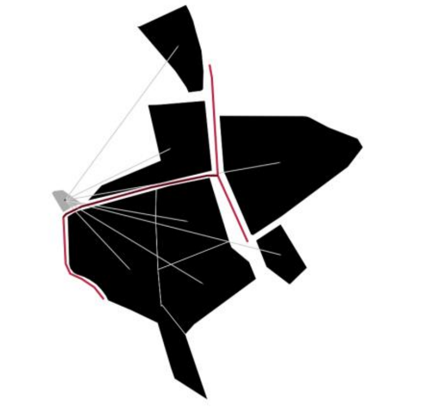

Figure 5.7: Shortest path calculation between parcels.

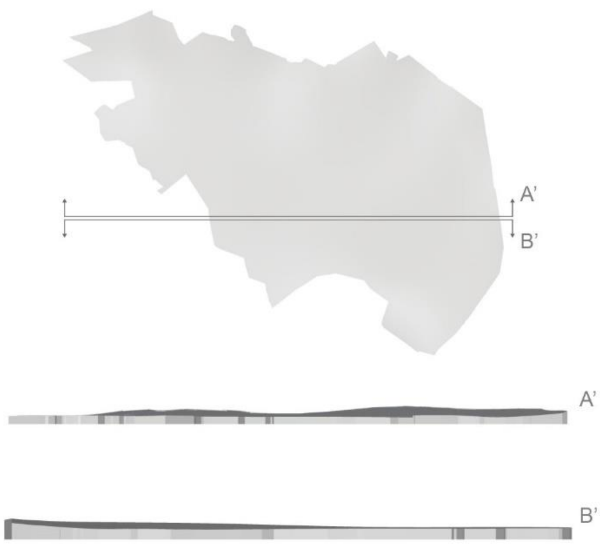

Figure 5.8: Topography of the area.

5.2.1 Analysis of scenario 1: current trend growing scenario

The first scenario consists of current land use and population projection for 2041. Minimum aerial requirements are calculated according to Spatial Plan Legislation (Mekansal Planlar Yapım Yönetmeliği, 2014) for the Göktürk neighbourhood with 70685 population. In Table 5.4, it is seen that all service areas are lower than the required area size. There exists Only 4.9% of the necessary green areas; only preschool and worship areas can meet above 20% of the needed area size. A 15-ha private golf area exists, but it is entitled under tourism areas in Implementation Plan legend standards, which means it cannot be counted as green space for the population. 98% of the educational area belongs to the private sector, and some kindergartens, primary, secondary schools and high schools share buildings/parcels. In addition, 25% of the health area belongs to the private sector.

Table 5.4: Analysis of areal adequacy for current trend growing scenario.

Services	M²/p	Min m²	The scenario of the current trend (m²)	The current trend (m²)
Preschool	0,5	1500-3000	35342,5	7899,8
Primary school	2	5000-8000	141370	14570,7
Highschool	2	6000-10000	141370	15467,8
Secondary school	2	6000-10000	141370	15248,1
Green area	10		706850	35249,8
1st stage health centre	1,5	750-2000	106027,5	6304,0
Sociocultural area	0,75		53013,75	5845,7
Small worship area	0,5	1000	35342,5	7929,4

To analyze the accessibility of current land use, firstly, the area was examined according to Spatial Plan Legislation's Radius rule (Figure 5.9). As a result, it was seen that high schools are located within a defined walking distance of the whole area, and secondary schools are almost entirely accessible in the entire area. In education and health accessibility, mostly private schools and hospitals increase the accessible area ratio. The walking distance was measured in health areas according to their size in Spatial Plan Legislation (Mekansal Planlar Yapım Yönetmeliği,2014). According to the legislation, health areas under 3000 m² are 1st step health centres with an accessibility distance of 500 m. In areas over 3000 m², no distance requirement is stated. However, since there is a lack of accessibility in the study area, the 3770 m² health area was also included in the accessibility analysis. In Spatial Plan Legislation, small worship areas are defined as areas under 2500 m². In these small worship areas, the walking distance is 250 m; for medium-sized worship areas, a 400 m walking distance is defined. According to this definition, two medium-sized worship areas and one small worship area exist in the existing land use.

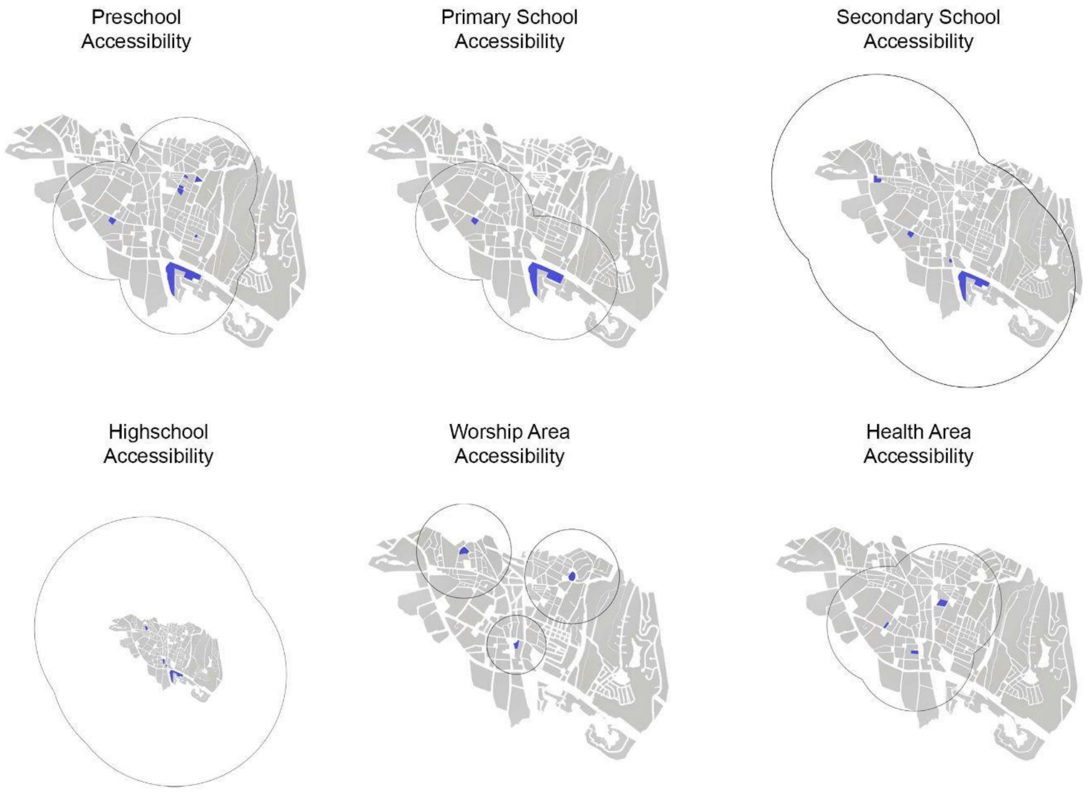

Figure 5.9: Accessible service parcels in current trend according to radius rule.

In spatial Plan Legislation, for green area classification, accessibility distance is only defined for children's playgrounds and open sports areas. However, green spaces have the potential to convert quickly into a playground. Therefore, total green space and children's playgrounds are analysed within 500 m walking distance to see the potential. Children's playgrounds are mainly located on the west side of the study area since the eastern side primarily consists of the gated community, Kemer Country Club (Figure 5.10).

Figure 5.10: Accessible green areas in current trend according to radius rule.

As mentioned in the beginning of Chapter 5, radius calculation is a primitive solution for the real world's complexity. Therefore, a more detailed analysis suitable for the actual situation, including the existing road structure, was made using the shortest path algorithm. Accessibility ratios of current land use decisions analysis were calculated in Grasshopper. According to analysis, the location of high schools can almost meet the accessibility distance in the whole area. Conversely, all other services cannot meet the accessibility needs of the Göktürk region (Table 5.5.).

Table 5.5: Accessibility analysis of current trend growing scenario.

Accessibility of current land use	Area m2	The total accessible area within a defined walking distance (m²)	Accessibility ratio (%)
Residential + commercial area	2.059.113,27		
Kindergarten	7.899,82	808746,3	39,3
Primary school	14.570,72	462492,47	22,5
Secondary school	15.248,06	1442199,2	70,0
Highschool	15.467,79	2036513,7	98,9
Children's playground	1.552,78	760582,2	36,9
Health area	6.307,92	631445,1	30,7
Worship area	7.938,34	359512,4	17,5
Public sports area	7.306,50	908999,3	44,1

5.2.2 Analysis of scenario 2: plan decisions scenario

The aerial requirements of the "1/1000 Implementation Plan for The Göktürk Neighbourhood Reserve Area Plan (2022)" and "Göktürk County Municipality 1/5000 Zoning Plan (2003)" were compared with defined standards according to the projected population of plans in Table 5.6. In addition to these uses, an atelier, two gas stations, one cemetery, one police station and a stream were defined in the Göktürk Implementation Plan. There is no designated high school in the area, but it can be expected that private education areas can meet these education demands, just like in current land use. But, there is no explanation about private education usage area legend in legislation standards or plan explanation reports.

Table 5.6 shows that only 18.04% of the green area can meet the plan decisions. Besides, since the usage content of the private education area is not specified, it is not understood whether the area decisions are sufficient for primary and secondary schools.

Table 5.6: Analysis of areal adequacy for plan decisions scenario.

Services	m²/p	Min m²	Ideal for the planned population	Plan decisions
Preschool	0,5	1500-3001 m²	50683 m²	990 m²
Primary school	2	5000-8000 m²	202732 m²	10981,3 m²
Secondary school	2	5000-8001 m²	202732 m²	9028,9 m²
Highschool	2	5000-8002 m²	202732 m²	-
Private education area				29360,88 m²
Children's playground	10			7312,07 m²
Park	10			2823,3 m²
Green area	10		1013660 m²	17,28 ha
Health area	1,5	750-2000 m²	152049 m²	3770 m²
Sociocultural area	0,75		76024,5 m²	5505,9 m²
Municipality service area				7832,76 m²
Private sport area				38611,52 m²
Private sociocultural area	0,75			8522,7 m²
Small worship area	0,5	1000 m²	50683 m²	4371,2 m²

For the accessibility ratio, the "1/1000 Implementation Plan for The Göktürk Neighbourhood Reserve Area Plan (2022)" and "Göktürk County Municipality 1/5000 Zoning Plan (2003)" were examined with Spatial Plan Legislation radius rule's accessibility distances but accessibility calculation was made by using A*Search algorithm. Secondary schools are almost entirely accessible within the planned area;

conversely, other services don’t meet the accessibility demand. For worship areas, an accessibility limit of 250 m is set for areas under 2500 m2 and 400 m for areas above 2500 m2. The content of the private education area mentioned in the plan is unclear, but when the current land use is analysed, it is seen that it contains preschool, primary school, middle school and high school. Therefore, in the analyses made for the plan decision scenario, this private education area was included in the kindergarten, primary school, secondary school, and high school uses, and the calculations were made accordingly (Figure 5.11).

Figure 5.11: Accessible service parcels in plan decisions according to radius rule.

For green areas, two different analyses were made, like in current land use: one is only for children's playgrounds, second includes parks, green spaces, and children's playgrounds. Figure 5.11 shows that the total green area is within the defined walking distance in the whole area, while children's playgrounds are not accessible.

After the radius analysis for the plan area, to examine how much the needs of the actual space can be met, accessibility was calculated according to the distance defined in the Plan Legislation standards with the shortest walk plug-in in Grasshopper.

When the accessibility of the plans made for the area is analyzed, it is observed that the site cannot meet the accessibility criteria for any service use (Table 5.7). Although the playgrounds or green areas within the gated communities can meet this demand for those within the housing estates, it has been determined that the fair accessibility demands of the increasing population of Göktürk cannot be satisfied with the plan decisions.

Table 5.7: Accessibility analysis of plan decisions scenario.

Land use types	Area (m²)	The total accessible area within a defined walking distance (m²)	Accessibility ratio (%)
Residential area	1889565,14		
Residential + commercial area	156163,88		
Total residential area	2045729,02		
Preschool	990	74744,7	3,7
Primary school	10989	1015741	49,7
Secondary school	10990	1712686	83,7
Children’s playground	10991	1019385,7	49,8
Health area	10992	241831,8	11,8
Worship area	10993	176263	8,6

5.2.3 Results of analysis

To conclude, Göktürk neighbourhood was examined according to its 2041 projected population in 2 scenarios. The first scenario analyzed how adequate the standards would be for the projected population with the existing land use/current trend. In the second scenario, it was examined if the "1/1000 implementation plan for the Göktürk neighbourhood reserve area" (2022) and "Göktürk county municipality 1/5000 Zoning Plan" (2003) plans for the area meet the standards according to the plan projection. Population projections were calculated as 70685 for the current trend and 101366 for plan scenarios. The scenarios were analyzed according to space adequacy and accessibility, and both scenarios remained far below the standards. Therefore, the standards as a guide in the system theory could neither be provided in the current trend nor the plans in Göktürk. Although all of these space and access requirements are possible in an ideal scenario, it is challenging in the complexity of the urban area. To reach the optimum, in the next chapter, alternative scenarios were created with optimization methods for a limited time and to allocate resources to the site as equally as possible.

5.3 Alternative Scenarios

It is seen in the analysis part that results were below the desired outcomes due to the complex structure of the spatial decision-making process and the cities' nature itself. Therefore, this chapter aims to show a way to reach desired outcomes as much as possible by creating alternative "optimized" scenarios.

Göktürk will not be able to provide fair land allocation for the projected year in terms of plan decisions and the continuation of the current trend. Even though private service areas are provided within the gated communities in Göktürk (while the population is increasing due to demand day by day), a fine spatial structure is not provided for outside of these gated communities.

After the analyses, the deficiencies in the plan decisions and the current growing trend of the area according to the Spatial Plan Legislation were determined. The gap between the ideal and current was detected and filling this gap was aimed. In the light of this situation, fitness objectives were determined as minimizing the difference between the current area and projected plan area requirement and maximizing accessible numbers of parcels for defined service areas stated in Figure 5.12. These fitness objectives' legal boundaries are described in the Spatial Plan Legislation according to population size or minimum required area size for specific service usage, and these defined boundaries became the search space of this study (Figure 5.12).

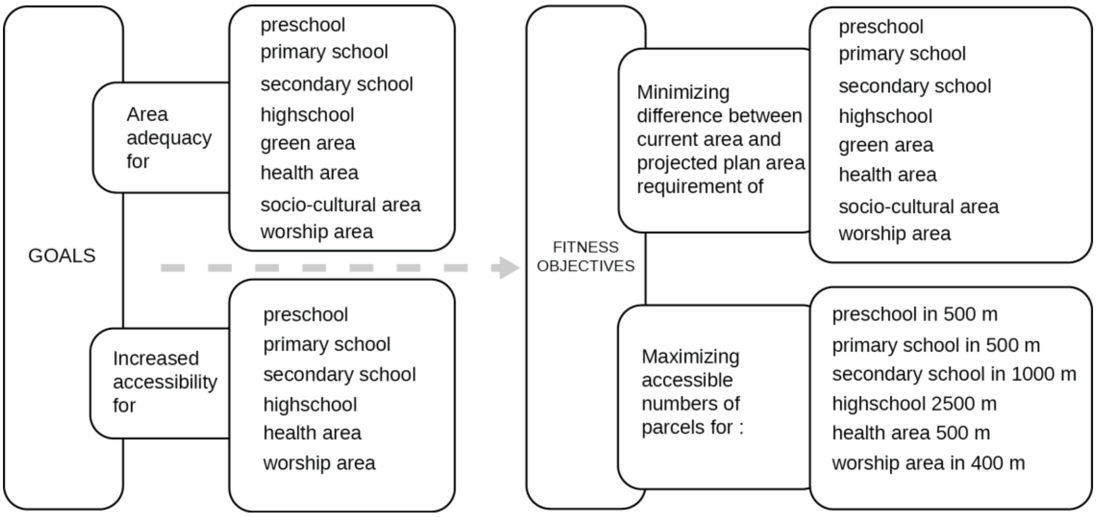

Figure 5.12: Goals and fitness objectives of the algorithm.

To show the potential of the study area to the urban planner/decision makers, three possible land allocation methods were considered for creating the best alternatives. In the first scenario, the deficiencies were identified when the land use demands were calculated according to the defined population projection in the analysis stage. After, plan decisions were tried to be optimized to complete these deficiencies in case the implementation of these decisions. In the second scenario, current land use decisions were tested according to population projection in case of not implementing the plan decisions but developing the area with newly added areas that came from optimization. In the final scenario, the question of "What kind of a land use plan would have emerged if the land use decisions were developed for the area only from the property boundaries and current road structure?" was investigated to get an idea about the ideal.

To summarize, an alternative creation process was made for three main scenarios:

I. plan decisions scenario

II. current trend growing scenario

III. scratch scenario

There are multiple methods for selecting solutions from the solution space like fittest for a specific fitness function, whole Pareto front solutions or closest solution to the ideal point etc. When choosing the best solution for a particular objective, it should be remembered that this result may be poor for other functions even though it is excellent for the selected one. For a selection from the Pareto front, the complexity of the problem may create a massive size of Pareto front solutions, which makes the selection process harder. Fitness objectives might be weighted differently to get closer to utopia, like the fittest for a specific function. In an equally weighted solution, all purposes are equally important and have "most equal weights among the fitness ranks", but this solution may not be located in the Pareto Front (Showkatbakhsh & Makki, 2022). To decrease the Pareto front solutions number, optimization problems should be simplified by reducing the number of fitness objectives or making it a single objective optimization. But in this study, since the aim is to show ideal scenarios specific to that service usage, the size of the Pareto front was excluded from the scope and interest. In addition, average fitness rank: 0 solutions for each scenario were also examined to see what kind of land use pattern would emerge if all fitness objectives were equally optimized.

5.3.1 Scenario 1: plan decision scenario

As part of the problem definition, land use decisions that did not meet the standards were identified as a result of the analyses. Therefore, scenarios for plan decisions and current trends were made to get the solutions which are as close to "ideal" as possible. The design process was built to reach "optimum" area sizes and accessibility ratios.

For the plan scenario, aerial requirements were calculated according to the projected population. The area adequacies were the first part of the optimization, for this part, it was tried to minimize the difference between the optimum and existing area size in the plan decisions (for the plan scenario). For accessibility, the topography of the area was introduced, roads were projected, the distances of randomly selected parcels to other parcels (except service areas) were calculated with the A* search algorithm. Then, the list of these distances was elected according to the limits defined in Spatial Plan Legislation standards. Finally, this list was tried to be maximized. Since the fitness objective has to be minimized for the Pareto front of multi-objective optimization, the length of this list (x) is multiplied by the negative and entered into the optimization. Initially, 1/x was tried to optimize the list, but it was observed that Wallacei plug-in work more efficiently with -x (Figure 5.13).

The algorithm was written in Rhinoceros 3D/Grasshopper, and Wallacei (Makki et al., 2018) plug-in was used for Multi-objective optimization. By using Wallacei, solutions were created, selected and visualized, for optimization and therefore, NSGA II was used as a genetic algorithm (Deb et al., 2000). Default settings of Wallacei were used for simulation values: generation size is 50, generation count is 100, crossover probability is 0.9, mutation probability is 1/n, crossover distribution index is 20, mutation distribution index is 20 and random seed of simulation is 1. As a result, the population size of the simulation was defined as 5000. For the plan scenario, there were 12 genes(sliders) in the algorithm, and the number of Fitness Objectives was 14 and therefore, the size of the search space is 1.5 x 10^29. The optimization was done with Intel(R) Core(TM) i7-8750H CPU @ 2.20GHz 2.21 GHz processor, and the simulation runtime was 6:59:09. In the testing phase, an optimization with 3000 population size took approximately 4.5 hours that point outs optimization duration can be decreased by using more powerful hardware.

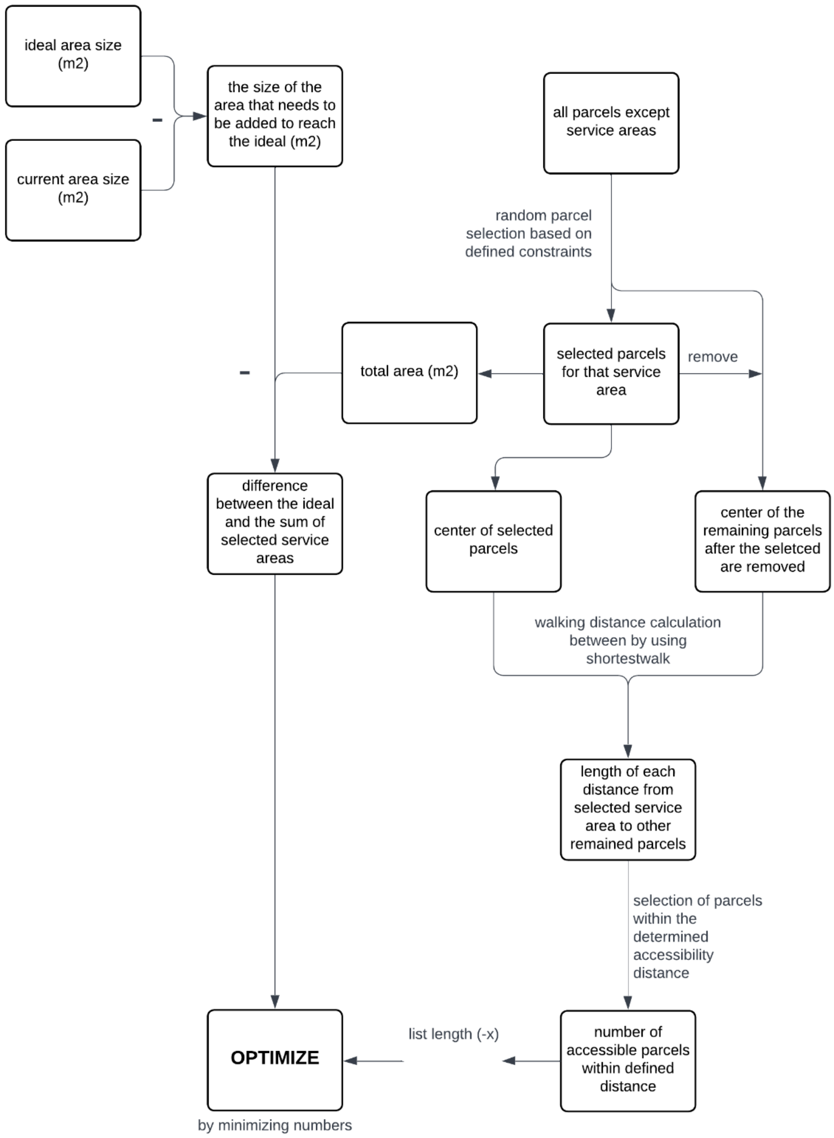

Figure 5.13: Pseudocode of the study.

For the plan scenario solutions, constraints of Fitness Objectives' genes were decided based on the Spatial Plan Legislation accessibility radius rule (Figure 5.14). It was calculated based on the question of how many parcels (n) are required for inaccessible areas according to Spatial Plan Legislation and for genes, the numbers are defined as [1, n+1]. Figure 5.8 shows radius rule results, that is, the input of constraints, and Table 5.8 shows the decisions for the plan scenario. Because Göktürk is a settlement above the neighbourhood scale defined in the literature, the worship areas to be proposed are not considered "neighbourhood mosques" but medium-sized worship areas and their limitations are calculated according to the radius rule over an accessibility distance of 400 m.

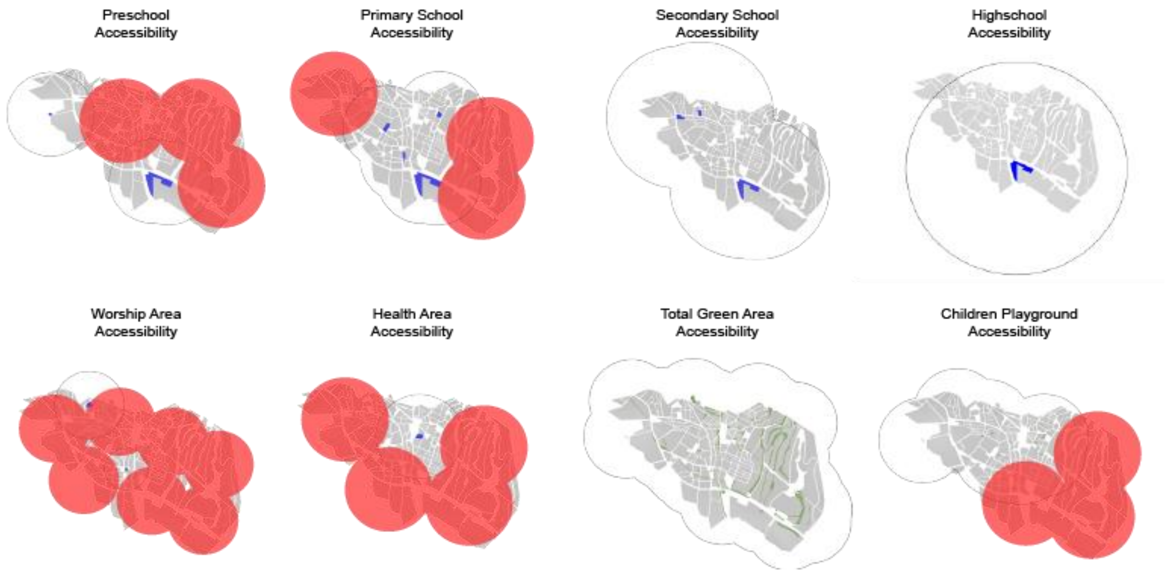

Figure 5.14: Radius rule as the constraint for plan decisions scenario.

Table 5.8: Searching space of parcel numbers for plan decisions scenario.

Constraints for fitness objectives of plan decisions scenario				
		preschool		4
		primary school		3
		secondary school		1
1	≤	high school	≤	1
		children's playground		4
		health area		5
		worship area		8

For areal adequacy, the ideal areal sizes were calculated according to the "Table of Standards and Minimum Area Sizes of Minimum Social and Technical Infrastructure

Areas in Different Population Groups" from Spatial Plan Legislation, which defines the minimum areal size of a service area for a person. In the light of this table, the children's playground area of 10 m^2 per person, the primary school area of 2 m^2 per person, the secondary school area of 2 m^2 per person, the health area of 1.5 m^2 per person, the worship area of 0.5 m^2 per person, preschool area of 0.5 m^2 per person, high school area of 2 m^2 per person were calculated for projected population 101366. Since existing socio-cultural sites provide aerial adequacy, there is no defined search for another socio-cultural area in the plan scenario.

As a result of the optimization, 532 Pareto front solutions were obtained, and from the last generation, only individual number 2 was located in the Pareto front. To understand the potential of every service usage in the plan decisions, the fittest solutions of every fitness objective were examined in Figure 5.15, and the optimisation results were compared in Figure 5.16, that red results are the best, while the greens have the worst fitness rank. The fitness diamond charts in Figure 5.17 compare fitness objectives' performance for every individual. In addition, the individual with an average fitness rank of 0 was added for an overall view. It is a fact that 532 Pareto front solutions are too many for a set of 5000 solutions, leading the decision maker to a new selection phase, but as mentioned, such a large number of Pareto front solutions can be expected due to the complexity of the problem. In this study, since the aim is to find the best solution for each objective and explore potential, the purposes of the multi-objective optimization have not been reduced or converted to a single-objective optimization problem. By looking at these results, the urban planner/decision-maker can choose the alternative that is the most crucial objective according to the problem. For example, if the accessibility of health areas for the Göktürk neighbourhood is preferred as the most critical problem, the solution Gen 26 Individual 0 will be selected (Figure 5.16).

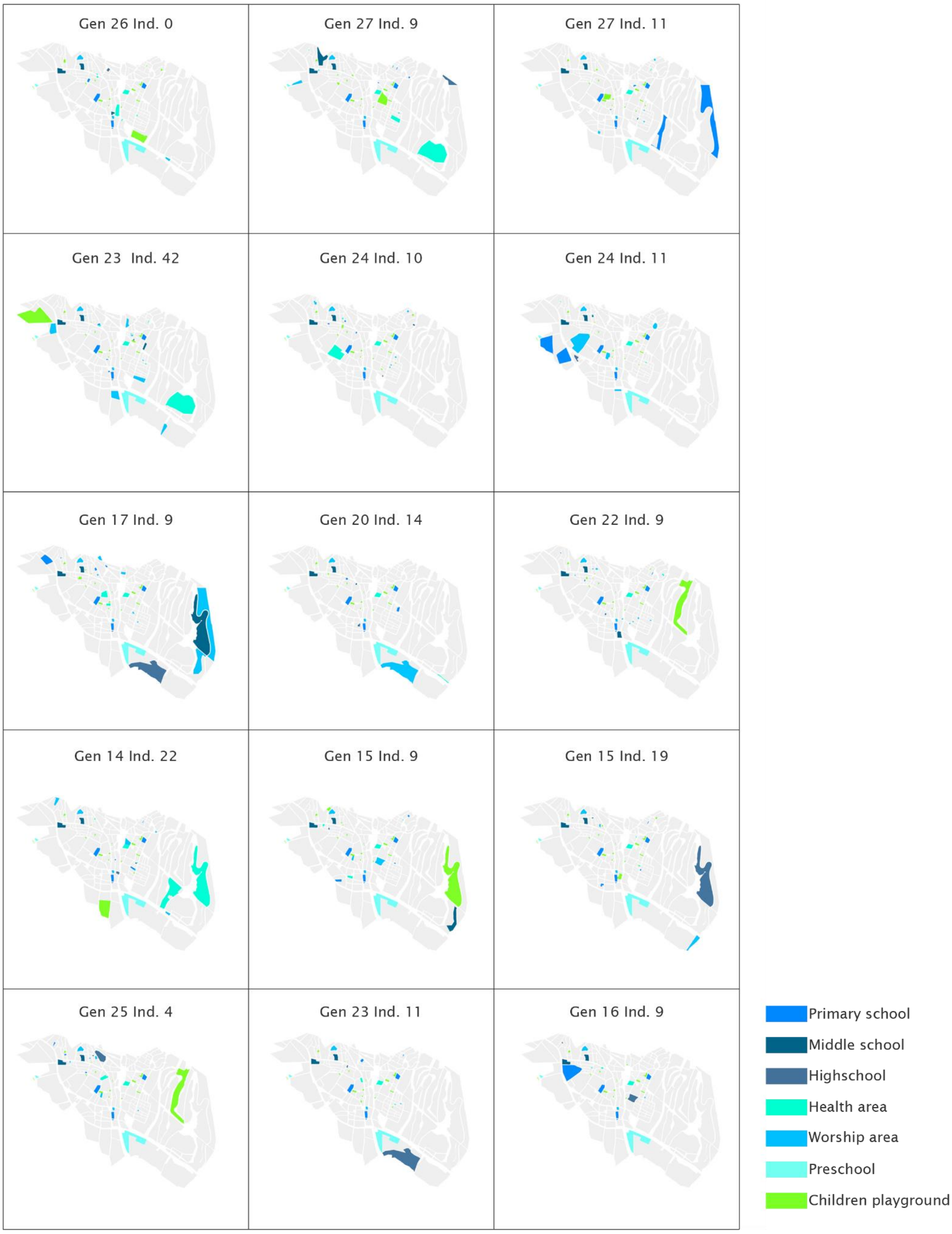

Figure 5.15: Fittest solutions of all fitness objectives for plan decision scenario.

	Fo1	Fo2	Fo3	Fo4	Fo5	Fo6	Fo7	Fo8	Fo9	Fo10	Fo11	Fo12	Fo13	Fo14
	maximum acessibility to highschool	maximum acessibility to worship area	maximum acessibility to health area	maximum acessibility to middle school	maximum acessibility to primary school	maximum acessibility to children playground	minimum difference for worhsip area (Ha)	minimum difference for primary school (Ha)	minimum difference for highschool (Ha)	minimum difference for middle school (Ha)	minimum difference for health area (Ha)	minimum difference children playground (Ha)	maximum acessibility to preschool	minimum difference for preschool (Ha)
Gen 14|Ind. 22	-833	-643	-461	-594	-440	-269	3,62	16,11	20,16	16,41	2,40	97,93	-83	1,85
Gen 15|Ind. 9	-829	-333	-584	-28	-441	-674	3,70	15,95	20,24	15,00	14,56	91,78	-346	1,65
Gen 15|Ind. 19	-575	-215	-459	-475	-510	-890	3,76	16,08	11,59	16,41	14,79	100,23	-304	2,00
Gen 16|Ind. 9	-842	-184	-540	-301	-153	-153	4,61	12,95	19,48	16,42	14,75	100,61	-346	1,90
Gen 17|Ind. 9	-832	-837	-415	-12	-503	-472	5,63	15,04	14,41	7,75	14,13	100,49	-149	1,92
Gen 20|Ind. 14	-841	-14	-17	-793	-453	-258	1,24	16,01	20,19	16,40	14,67	100,60	-115	0,35
Gen 22|Ind. 9	-826	-1494	-168	-463	-502	-660	4,41	16,18	20,24	16,04	14,78	95,34	-347	1,77
Gen 23|Ind. 11	-840	-162	-488	-696	-382	-390	4,61	16,11	14,41	16,40	14,67	100,57	-550	1,93
Gen 23|Ind. 42	-827	-770	-862	-585	-668	-273	1,11	16,13	20,24	16,22	7,83	95,39	-470	1,85
Gen 24|Ind. 10	-829	-678	-355	-413	-820	-815	4,39	16,13	20,25	16,40	12,51	100,45	-121	1,98
Gen 24|Ind. 11	-835	-673	-286	-510	-24	-214	0,03	11,20	20,05	16,39	14,80	100,62	-243	1,50
Gen 25|Ind. 4	-837	-855	-239	-509	-508	-4	4,35	16,10	19,18	16,42	14,45	95,42	-164	0,01
Gen 26|Ind. 0	-836	-15	-1257	-681	-256	-687	4,48	16,12	20,17	16,31	14,05	98,82	-259	3,90
Gen 27|Ind. 9	-827	-304	-521	-325	-540	-1040	4,22	16,16	19,57	15,03	7,33	99,16	-129	1,87
Gen 27|Ind. 11	-831	-509	-175	-556	-315	-871	4,43	6,82	20,26	16,41	14,80	99,96	-188	1,98
*smallest value (red) gives the best result														

Figure 5.16: Results of multi-objective optimization for fittest solutions of all fitness objectives in plan decision scenario.

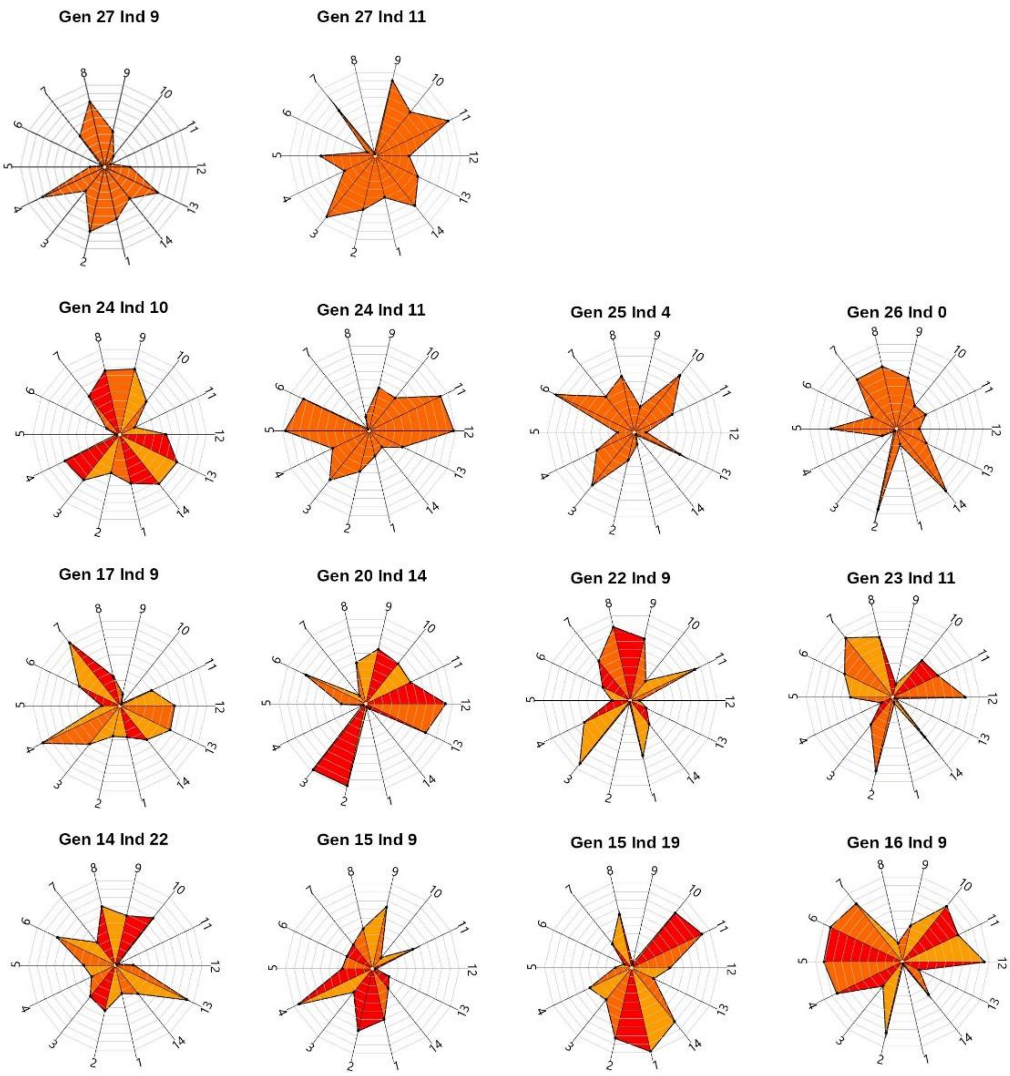

Figure 5.17: Diamond fitness charts of plan decision scenarios.

Average of fitness ranks 0: gen 23 ind. 42

To get a more detailed view, the average fitness rank: 0 alternative for plan decisions scenario was analysed. In this alternative, especially health, worship and children's playground area sizes increased dramatically. It was seen that, there is an aerial increase of 717% for children's playgrounds, 2.7% for primary schools, 5.5% for secondary schools, 1856% for health areas, 805% for worship areas and 5.9% for preschools. In addition, a 284 m² location for high schools was added. If it is accepted that the private education area includes high school, it can be said that there is an increase of 1.09% in high school fields. Since there is no restriction on the minimum area selection, an insufficiently sized parcel (284 m²) was selected for the high school. As mentioned in the limitations section, area sizes can be chosen more efficiently in future studies by introducing constraints on area size. To increase accessibility, 272 more parcels have access to children's playgrounds, 668 more parcels have access to primary schools, 585 more parcels have access to secondary schools, 827 more parcels have access to selected high schools, 862 more parcels have access to health areas, 770 more parcels have access to worship areas, and 470 more parcels have access to preschools in the alternative Gen 23 Ind. 42. The diamond fitness chart (Figure 5.18) shows the performances of fitness objectives of Generation 23, individual 42, and Table 5.9 determines the rank of each fitness objective.

Table 5.9: Fitness results of gen 23 ind. 42 in optimization of plan decisions scenario.

Fitness objective	Fitness rank	Within
accessibility to worship areas	1790	4999
accessibility to health areas	796	
accessibility to secondary schools	1766	
accessibility to high school	3020	
accessibility to primary schools	279	
accessibility to children's playground	3625	
accessibility to preschool	261	
the minimum difference for worship areas	310	
the minimum difference for primary schools	3651	
the minimum difference for secondary schools	1382	
the minimum difference for children's playground	468	
the minimum difference for preschools	2006	
the minimum difference for health areas	436	

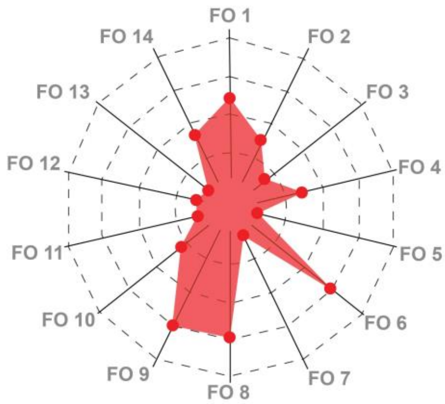

Figure 5.18: Diamond chart of gen 23 ind. 42 in optimization of plan decisions scenario.

5.3.2 Scenario 2: current trend growing scenario

For the current trend scenario, the same algorithm structure in the plan decision scenario was used (Figure 5.13). The fitness objectives' searching range was decided from the Spatial Plan Legislation accessibility radius rule (figure 5.19). Just like in the plan decision scenario, required parcel numbers according to radius rule (n) were identified, and the searching range (gene pool) was defined as [1, n+1]. Table 5.10 shows the searching space of parcel numbers for the current trend growing scenario. In this scenario, recent land use accessibility analysis indicated that high schools are available within the whole area, so no new high school area has been proposed. For proposed worship areas, the accessibility distance was decided as 400 m since Göktürk is above the neighbourhood scale mentioned in the plan decision scenario (Figure 5.19).

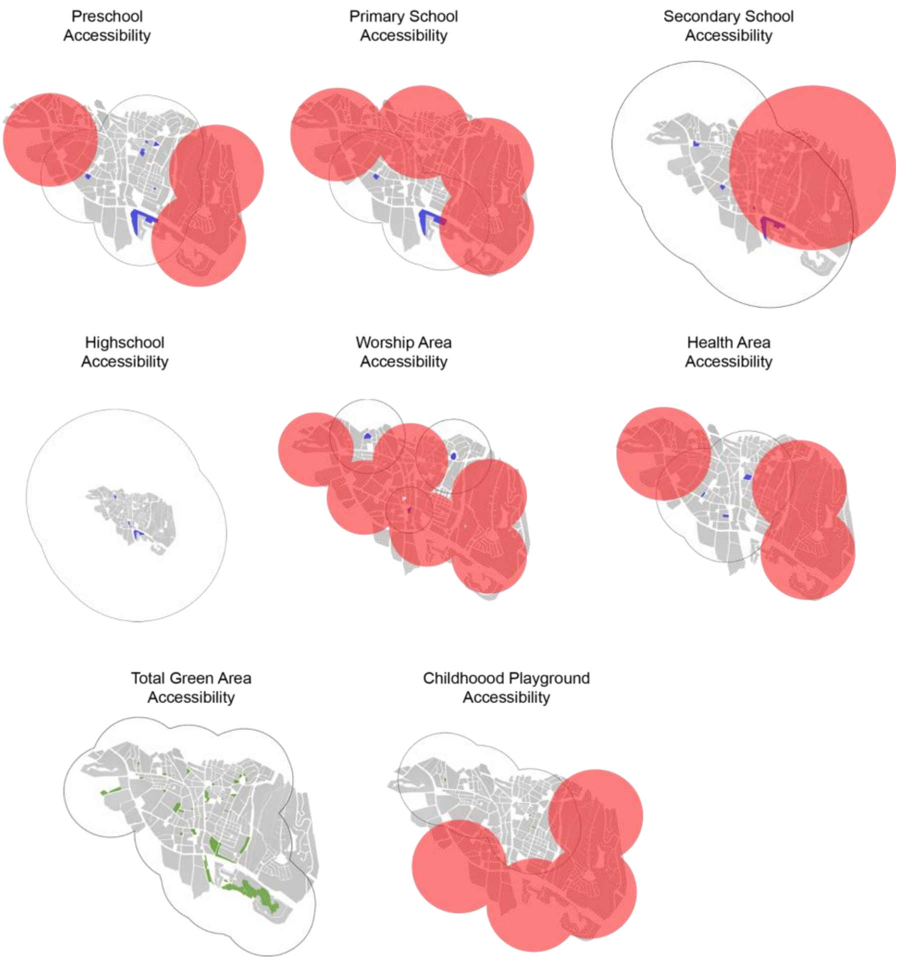

Figure 5.19: Radius rule as the constraint for the current trend-growing scenario.

Table 5.10: Searching space of parcel numbers for current trend growing scenario.

Constraints for fitness objectives of the present current trend growing scenario				
1	≤	preschool	≤	4
		primary school		5
		secondary school		1
		children’s playground		5
		health area		4
		worship area		7

For current trend growing scenario optimization, just like the plan decision scenario, default optimization settings of Wallacei (Makki et al., 2018) were used, which the generation size is 50 and generation count is 100 with 0.9 crossover probability, 1/n mutation probability and random seed is 1. The optimization duration was 13:24:03; 1123 Pareto front solutions were created; generation no. 99 was all in the Pareto front. To understand how well the area optimized for each fitness objective, the fittest alternatives of the fitness objectives (Figure 5.20) and the performance of each individual among others (Figure 5.21) were identified. Just like in the first scenario, for an overall view, the individual with an average fitness rank of 0 was also determined for an overall view.

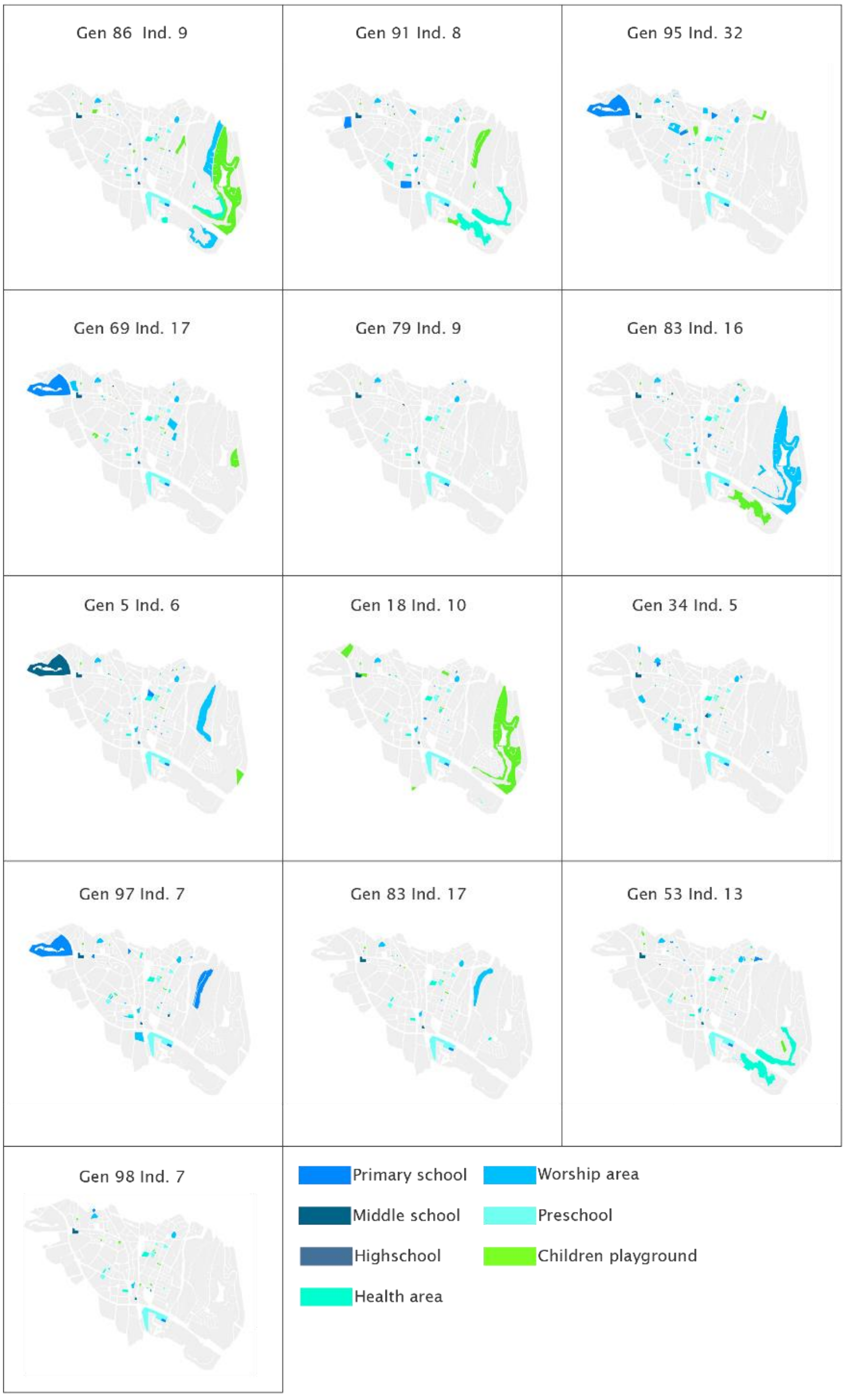

Figure 5.20: Fittest solutions of all fitness objectives for current trend growing scenario.

	Fo1	Fo2	Fo3	Fo4	Fo5	Fo6	Fo7	Fo8	Fo9	Fo10	Fo11	Fo12
	maximum acessibility to worship area	maximum acessibility to health area	maximum acessibility to middle school	maximum acessibility to primary school	maximum acessibility to children playground	minimum difference for worhsip area (Ha)	minimum difference for primary school (Ha)	minimum difference for middle school (Ha)	minimum difference for health area (Ha)	minimum difference children playground (Ha)	maximum acessibility to preschool	minimum difference for preschool (Ha)
Gen 5|Ind. 6	-853	-798	-282	-1052	-171	2,35	10,66	4,22	9,81	69,62	-277	0,02
Gen 18|Ind. 10	-181	-497	-491	-794	-466	2,68	11,04	10,89	9,78	50,65	-122	0,12
Gen 34|Ind. 5	-960	-357	-725	-808	-215	1,13	10,78	10,81	9,87	70,51	-340	0,00
Gen 53|Ind. 13	-1395	-165	-490	-921	-451	2,45	10,71	10,90	0,51	69,89	-94	0,12
Gen 69|Ind. 17	-1062	-1090	-546	-22	-717	0,46	4,45	10,90	9,78	68,67	-294	0,07
Gen 79|Ind. 9	-103	-32	-790	-153	-243	2,64	11,11	10,89	9,95	70,52	-173	0,08
Gen 83|Ind. 16	-658	-355	-629	-1187	-364	15,97	10,88	10,88	9,90	65,32	-554	0,04
Gen 83|Ind. 17	-475	-708	-426	-262	-293	0,00	11,14	10,92	9,80	70,50	-111	0,12
Gen 86|Ind. 9	-192	-74	-596	-1342	-857	4,58	10,92	10,91	6,99	51,44	-161	0,06
Gen 91|Ind. 8	-848	-355	-674	-914	-332	2,32	9,02	10,91	0,06	66,38	-347	0,06
Gen 95|Ind. 32	-1075	-1002	-541	-897	-1212	0,24	3,70	10,90	9,77	69,28	-309	0,07
Gen 97|Ind. 7	-678	-852	-561	-712	-911	1,29	0,87	10,85	9,67	70,44	-136	0,12
Gen 98|Ind. 7	-200	-168	-607	-192	-1403	2,68	11,04	10,90	9,93	70,29	-335	0,06

*smallest value (red) gives the best result

Figure 5.21: Resuts of multi-objective optimization for fittest solutions of all fitness objectives in the current trend-growing scenario.

Average of fitness ranks 0: gen 95 ind. 32

The average fitness rank:0 solution for the current trend scenario was examined to analyse performances in more detail. In this alternative, as a result, there is an increase of 250% in primary school areas, 806% in playground areas, 0.7% in secondary school areas, 30% in health areas, 74% in worship areas and 6.3% in kindergarten areas. In addition, 897 more parcels have access to primary schools, 1212 more parcels have access to playgrounds, 541 more parcels have access to secondary schools, 1002 more parcels have access to health areas, 1075 more parcels have access to worship areas, and 309 more parcels have access to kindergarten areas. Before the optimization, current accessible parcel numbers for kindergartens were 568, primary schools were 163, secondary schools were 755, children's playgrounds were 610, health areas were 383, worship areas were 434, and high schools were 888. To understand the overall performance of this individual within 5000 solutions, the rank of each objective was determined in Table 5.11, and it was seen that fitness objective 2 (accessibility to health areas) has the best rank (Figure 5.22)

Table 5.11: Fitness results of gen 95 ind. 32 in optimization of current trend growing scenario.

Fitness objective	Fitness rank	Within
accessibility to worship areas	335	
accessibility to health areas	108	
accessibility to secondary schools	2140	
accessibility to primary schools	1422	
accessibility to children's playground	147	
accessibility to preschool	910	4999
the minimum difference for worship areas	221	
the minimum difference for primary schools	211	
the minimum difference for secondary schools	3816	
the minimum difference for children's playground	1496	
the minimum difference for preschools	1822	
the minimum difference for health areas	2853	

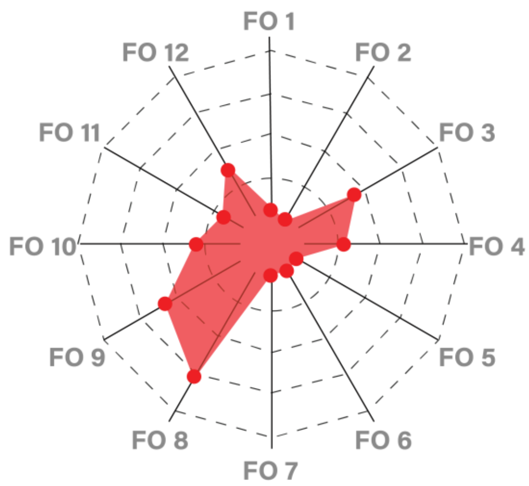

Figure 5.22: Diamond chart of gen. 95 ind.32 in optimization of current trend growing scenario.

5.3.3 Scenario 3: scratch scenario

The same algorithm structure in the plan decision and current trend scenario was also used for the scratch scenario with minor additions. In this scenario, it was assumed that there were no defined land use decisions. For the decision-making, parcels were identified by overlapping property boundaries. Current land use data obtained from Eyüpsultan Municipality and roads structure were accepted as roads of existing land use. For deciding the needs of the area, current trends' population projection was carried out for service area calculations. Just like plan decisions and current trend scenarios, areal requirements of the site were identified according to “Spatial Plan Legislation” (Mekansal Planlar Yapım Yönetmeliği, 2014) “Table of Standards and Minimum Area Sizes of Minimum Social and Technical Infrastructure Areas in Different Population Groups”. In this scenario, due to creating the land use decisions from zero, minimum area sizes from the “Table of Standards and Minimum Area Sizes of Minimum Social and Technical Infrastructure Areas in Different Population Groups” are used as constraints. By implementing these constraints, searching space was minimized, which is beneficial for optimization runtime. In light of these constraints, primary school areas were selected for over 5000 m² parcels; secondary schools were selected for over 6000 m² parcels; health areas were selected for over 750 m² parcels; worship areas were selected for over 1000 m² parcels, preschools were selected for over 1500 m², and high schools were selected over 6000 m² parcels. Due to no defined socio-cultural areas in plan decisions and current trend scenarios, socio-cultural areas were also excluded in this scenario.

For accessibility, the radius rule was implemented, and for deciding the search space of fitness objectives (Figure 5.23), constraints [1, n+1] were defined the same as plan decisions and current trend scenarios (Table 5.12).

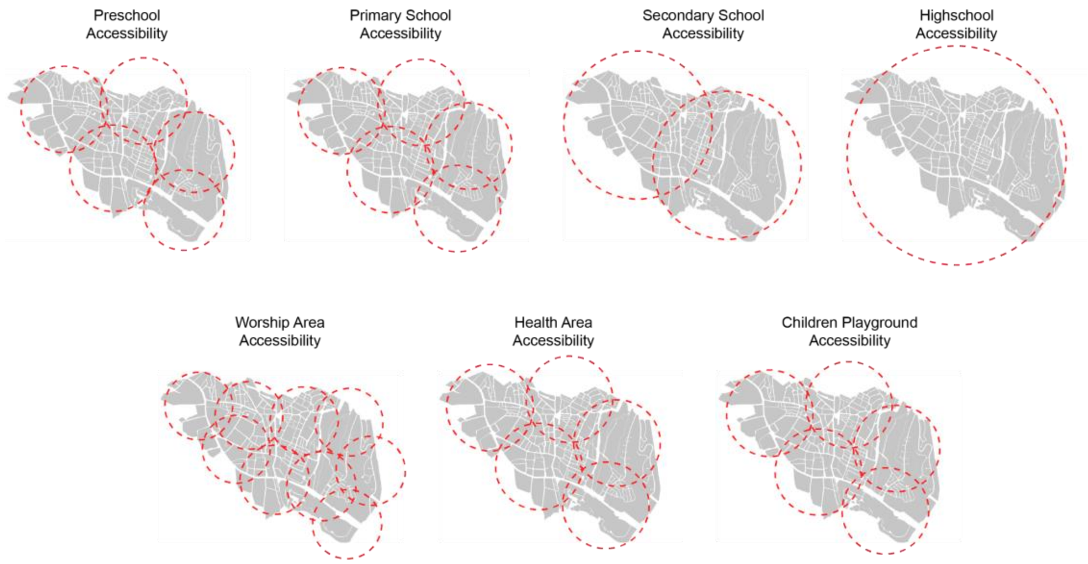

Figure 5.23: Radius rule as the constraint for the scratch scenario.

Table 5.12: Searching space of parcel number for the scratch scenario.

Constraints for fitness objectives of the current trend-growing scenario				
1	≤	preschool	≤	6
		primary school		6
		secondary school		2
		children's playground		6
		health area		6
		worship area		10
		High school		1

*n+1 rule wasn't implemented in high school and secondary schools due to the size of the radius

In the scratch scenario, the default optimization settings of Wallacei (Makki et al., 2018) are the same as plan decisions and current trend scenarios. The generation size was defined as 50, and the generation count was 100 with 0.9 crossover probability, 1/n mutation probability, and the random seed was 1. Unlike the other simulations, the simulation runtime was way higher than others, as 32:5:9. The increase in simulation runtime can be expected due to there is no predefined parcels for service areas so searching space is much higher than other scenarios. In scratch scenario 1180, Pareto front solutions emerged, and generation No.99 was all in the front. To eliminate the answers and see the area's potentials, the fittest alternatives for every fitness objective (Figure 5.24) were determined, ranks of every fitness objective for each individual were compared (figure 5.25), and average fitness rank :0 was represented.

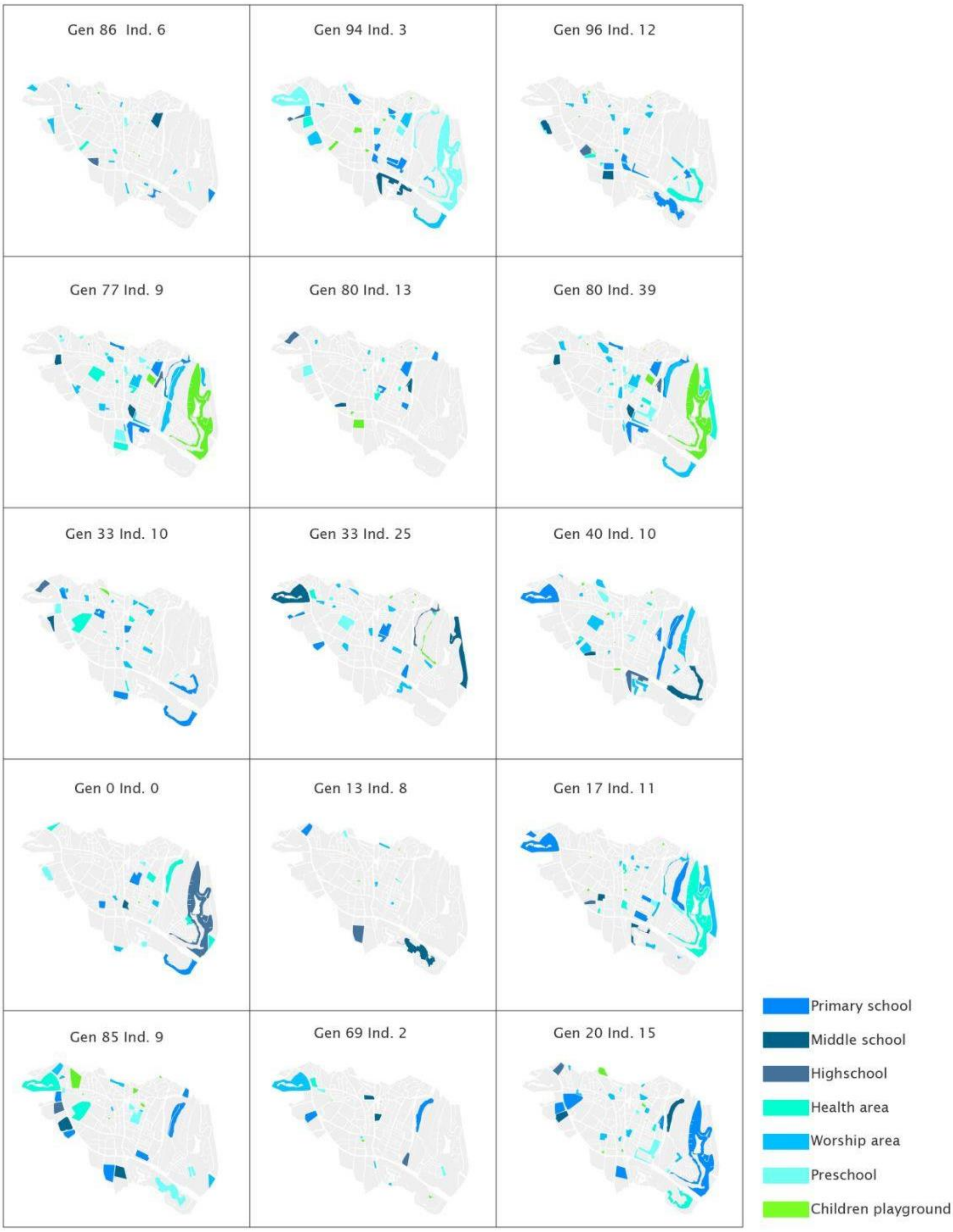

Figure 5.24: Fittest Solutions of all Fitness objectives for the scratch scenario.

	Fo1	Fo2	Fo3	Fo4	Fo5	Fo6	Fo7	Fo8	Fo9	Fo10	Fo11	Fo12	Fo13	Fo14
	maximum acessibility to worship area	maximum acessibility to health area	maximum acessibility to middle school	maximum acessibility to primary school	maximum acessibility to children playgroun d	minimum difference for worhsip area (Ha)	minimum difference for primary school (Ha)	minimum difference for middle school (Ha)	minimum difference for health area (Ha)	minimum difference children playgroun d (Ha)	maximum acessibility to preschool	minimum difference for preschool (Ha)	maximum acessibility to highschool	minimum difference for highschool (Ha)
Gen 0|Ind. 0	-335	-412	-568	-394	-693	2,13	8,71	13,48	4,83	70,61	-386	1,13	-398	3,76
Gen 13|Ind. 8	-557	-255	-9	-61	-637	2,86	12,94	9,58	10,52	70,59	-196	3,21	-926	11,46
Gen 17|Ind. 11	-650	-899	-873	-372	-1291	5,74	0,04	12,50	8,65	70,40	-224	2,34	-905	13,52
Gen 20|Ind. 15	-1477	-202	-680	-411	-1287	0,34	11,49	10,05	7,39	69,49	-1049	0,00	-868	12,94
Gen 33|Ind. 10	-1467	-1296	-405	-746	-620	0,00	4,75	13,19	5,73	70,25	-162	2,33	-858	12,80
Gen 33|Ind. 25	-1256	-155	-288	-653	-959	1,38	9,26	1,40	9,76	69,61	-522	0,75	-903	12,85
Gen 40|Ind. 10	-837	-245	-520	-215	-1106	8,38	1,43	8,67	10,13	70,24	-1660	0,78	-901	11,54
Gen 69|Ind. 2	-41	-361	-1583	-37	-637	3,45	10,05	12,85	9,79	70,45	-257	2,78	-921	13,17
Gen 77|Ind. 9	-723	-1226	-930	-326	-924	8,06	7,83	12,09	5,60	51,70	-1083	0,11	-903	13,32
Gen 80|Ind. 13	-178	-1599	-1020	-697	-387	3,19	10,61	12,69	9,34	69,11	-64	1,99	-866	12,80
Gen 80|Ind. 39	-1122	-1055	-933	-329	-927	7,75	7,83	12,09	3,47	51,70	-1455	0,27	-903	13,31
Gen 85|Ind. 9	-456	-236	-832	-332	-1227	0,33	4,07	9,95	0,00	67,47	-683	4,25	-895	12,59
Gen 86|Ind. 6	-491	-306	-482	-13	-1559	0,61	12,67	12,38	9,78	70,49	-297	2,72	-911	13,23
Gen 94|Ind. 3	-935	-61	-493	-1434	-1209	6,60	8,75	10,33	9,06	69,18	-566	23,88	-887	13,52
Gen 96|Ind. 12	-1771	-472	-683	-743	-914	0,05	5,99	11,24	4,74	70,45	-34	2,88	-902	12,77

*smallest value (red) gives the best result

Figure 5.25: Results of multi-objective optimization for fittest solutions of all fitness objectives in the scratch scenario.

Average of fitness ranks 0: gen 80 ind. 39

In this alternative of scratch scenario, worship areas are accessible for 1122 parcels; health areas are accessible for 1055 parcels; secondary schools are accessible for 933 parcels; primary schools are accessible for 329 parcels; children's playgrounds are accessible for 927 parcels within defined distances. And, children's playgrounds are 18.9 ha with a difference of 51.7 ha, primary schools are 6.3 ha with a difference of 7.8 ha, secondary schools are 2.04 ha with a difference of 12 ha, health areas are 7.1 ha with a difference of 3.4 ha, worship areas are 11.2 ha with a difference of 7.7 ha, preschools are 3.2 ha with a difference of 0.26 ha, high school area is 0.8 ha with 13 ha difference of 13 ha to ideal. In this scenario, children's playgrounds also can be named active green areas because the children's playground area was calculated to be 10 m² per person, which meets the total green space requirement specified by the standards. In total, it is seen that this individual is 1st in all solutions as rank = 0 (Table 5.13) in terms of fitness objective 10 - areal adequacy for children's playground, that was also visualized in diamond chart Figure 5.26.

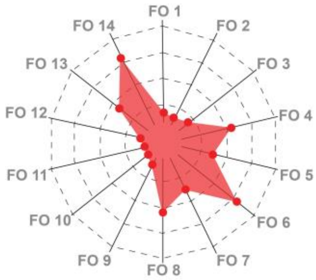

Figure 5.26: Diamond chart of gen 80 ind. 39 in optimization of scratch scenario.

Table 5.13: Fitness results of gen 80 ind. 39 in optimization of scratch scenario.

Fitness objective	Fitness Rank	Within
accessibility to worship areas	901	4999
accessibility to health areas	744	
accessibility to secondary schools	1001	
accessibility to primary schools	2856	
accessibility to children's playground	1924	
accessibility to high school	1985	
the minimum difference for worship areas	4009	
the minimum difference for primary schools	1852	
the minimum difference for secondary schools	2763	
the minimum difference for children's playground	0	
the minimum difference for preschools	304	
the minimum difference for high school	4007	

5.4 Chapter Evaluation

Three main experiments were made to see the new space design possibilities. Within 15000 solutions, 43 were evaluated in detail: 40 for the fittest of each parameter, 3 for average fitness rank:0. Some alternatives got the best result for related parameters while others remained poorly unsatisfied. For example, in the scratch scenario, Gen 96 Ind. 12 gave the best outcome for maximum accessibility to the worship area. Still, at the same time, maximum accessibility to preschool was worst among other alternatives examined (Table 12). Many different selection and analysis methods exist for individuals in the Wallacei plug-in (Makki et al., 2018), which eases the evaluation stage. However, only the fittest solutions of each parameter and average fitness rank: 0 were displayed here. From that point, deciding among created alternatives is up to the decision maker’s priorities that builds a new research question for further studies.

6. CONCLUSION

This study introduces a method for the decision-making process in the conventional urbanism approach that accommodates the complexity of the city. The generative design was used in this framework to deal with that complexity. In that scope, the study first discussed the evolution of traditional cities to complex urban systems to understand the problems of urban areas.

Professionals, to find solutions to the urbanization problems that grew with industrialization, deemed it appropriate to approach cities with a systematic perspective and first examined cities with the general system theory. As a result, cities were defined as open systems/emergent properties consisting of multiple systems and influencing other systems. Professionals described these relationships were defined hierarchically by professionals, and it was advocated by them that they should be resolved through top-down methods. However, with the development of complexity theory, professionals later stated that urban systems are actually not hierarchical. It was observed that they exhibit constantly changing characteristics and any agent can randomly affect the system at any time. As a result, they were found to demonstrate bottom-up, non-linear, chaotic, unpredictable, and dynamic characteristics. Producing solutions to problems in these rapidly changing urban systems has become almost impossible with human power alone, and the long urban planning process often skips the alternative creation stage, struggling to keep up with the rapidly changing city, and advances the process through a single option without the planner control over potential solutions. In this process, the urban planner is expected to have control over all parameters and agents involved in the entire process, but this is almost impossible in a constantly changing, chaotic complex system. In light of these results, decision-making tools that can assist the urban planner in the decision-making process were discussed in the study context.

It is seen that decision-making tools can vary from a single mathematical method to real-time data simulation. Within this variety, to catch the complexity of the city today, computational decision-making tools are the most popular tools that can ease the decision-makers work, and the most common tools used in urban planning are Geographic Information Systems, Artificial Intelligence Applications and Computational Design tools. Each of them is very powerful in many steps of the urban planning/decision-making process. For example, GIS can be used for analysing the existing situation, representing the potential solutions, evaluating them and selecting from them with the collaboration of other tools like AI. AI can be used in the problem definition of urban space by detecting anomalies; it can help in the alternative selection stage with its optimization tools. Apart from these, it is seen that computational design is a powerful tool in the alternative generation stage which enables to design of the process, not the product itself. This allows the urban planner to adapt quickly to the complex city's rapidly changing problems and reduce time and cost by making small changes in the process rather than creating a solution from zero for the constantly evolving situation. In addition, computational design can create thousands of alternatives in seconds that human power cannot handle. Therefore, generative design -a subset of computational design- was used as a base decision-making tool in this study due to its ability to create multiple alternatives and select from them.

Using these decision-making tools, a bottom-up "ideal search" study was conducted in Göktürk, a highly complex area within the spatial standards defined in the Turkish planning system that exhibits a top-down characteristic. It was determined that, just like in other Turkish cities, there is no equal use of space for everyone in this area of high complexity; moreover, the equality that cannot be achieved in the current situation is also the same in the plan decisions. The aim here is to demonstrate the potential of the space to the urban planner by producing scenarios that meet the increasing demand for space as much as possible within the limits of the standards for increased accessibility and area adequacy, thus ensure a fair production of space.
To this end, Göktürk was examined in two different situations to identify demand. In the first situation, a population projection (70685) was made for 2041, 20 years after the start of this study, and the adequacy of service areas in terms of accessibility and area size was examined, assuming that the current land use would continue in the same way. In the second situation, the population determined by the spatial plans for Göktürk (101366) was identified, and the adequacy of spatial plans was examined. The adequacy was analysed for minimum area requirements from Turkish planning

standards and accessibility ratio of the area according to planning standards for health area, worship area, kindergarten, primary school, secondary school, high school and children's playground. When analyzed for space adequacy, it was found in currrent situation, some education and health areas are in private parcel ownership. But throughout the study, ownership was not considered due to data about parcel ownership couldn’t be obtained. The accessibility analysis was made by shortest path finding, not the traditional radius calculation, and it was seen that, both for area adequacy and accessibility, only high schools are nearly accessible within the whole area in current land use. On the contrary, no defined high school area exists in spatial plans.

After defining the deficiencies, three major scenarios were planned to show the potential of Göktürk. The first scenario was made with new service area additions to existing land use in case no plans were implemented. The second scenario was about filling the gaps between plan decisions and the minimum requirements of the projected population. Finally, in the last scenario, it was aimed to see the full potential of Göktürk for 70685 people and only property boundaries were used as a base for future service area decisions.

An algorithm was developed for the scenarios in Rhino’s open-source plug-in Grasshopper that enables visual coding. The algorithm’s parameters were the location and number of parcels of health area, worship area, kindergarten, primary school, secondary school, high school and children's playground. After the scenario was built with these parameters, algorithms were optimized to maximize the number of accessible parcels and minimize the difference between the ideal area size and the generated alternatives by the Wallacei plug-in.

In total, 15000 alternatives with 2835 Pareto front solutions were created in 52 hours 28 min. Scenario 3 took too long because there was no defined service area, so the search space was much wider others. With these outputs, it can be easily said that selection from alternatives is still an issue for decision-makers. To narrow the selection space and see potentials, the fittest solutions for each parameter in every scenario were demonstrated, in addition, the individual in which each parameter is optimized at the same level was identified. These solutions show that there is no good solution for this complex problem, but the urban planner can select the ‘’good enough’’ one in the defined context/problem.

This study is an attempt to prevent the urban planner from wasting time on small decisions and to put the planner in the position of the process controller. However, even though the power of this framework was demonstrated, there still exist some challenges about it.

In the “plan decisions scenario” and “current trend growing scenario”, there is no limit on the minimum parcel size for the selected parcels. Therefore, there is a possibility that service area selection may be made in parcel sizes below those allowed by the Spatial Plan Legislation. Further studies can narrow the search space by adding these limits and obtain suitable solutions for legislation. As another limitation of this thesis, fitness values for accessibility to residential areas were calculated by maximizing the size of the accessible parcel list, the calculation was made in this way due to the capacity of hardware which used during this study. This calculation can be made by maximizing the percentage of accessible parcels’ area, but calculating the parcel area will take more time, and it needs more powerful hardware technology. In addition to accessibility- related limitations, accessibility analyses were made using defined road structures in all scenarios. Road structure can be generated as a different approach, and location decisions can be made after developing road alternatives in future studies.

Another limitation for of this study is that the parcel selections were made from parcels where existing health areas, worship areas, kindergartens, primary schools, secondary schools, high schools and children's playgrounds were excluded, which means there are no defined new housing or commercial areas in the designed space. This approach builds a new problem, the allocation of residents, which may be solved by different methods for increasing density. These kinds of problems may lead to rethinking the legal boundaries and abilities in Turkish plans and regulations. Walking distance and, areal adequacy can be changed according to physical space, population growth, density and other socio-economical needs. Besides, as it mentioned that parcel ownership was not considered in the study, which brings a new perspective for further studies. For these service areas, new defined parcels were accepted as public properties. In further studies, parcel ownership can be added as a parameter directly to the study of site-specific expropriation processes can be questioned from different perspectives using these tools.

From another perspective, concepts like resilient cities, transit-oriented development, 15 min cities, healthy cities etc., can be easily implemented with defined parameters for both existing and new areas. This study was made within the limits of Turkish spatial planning standards, in further studies, standards can be defined specific to area's needs by using this framework. Standards, parameters may be defined according to natural, social needs of the system. This framework has the potential to easy implementation of new theories for more resilient solutions to complex city problems. In addition to creating cities with numerous alternatives, a selection from them can be made by using other approaches such as participatory planning and, gamification. Moreover, these approaches can be combined, and final results can be presented to actors to make the final decision.

Rhino Grasshopper provides a simple user interface for visual coding, which means it does not need any coding skills, but since high complexity brings multiple parameters, tracking the algorithm becomes tough. Still, it does require knowing how to visual coding. This visual code can be implemented to any script, and user-friendly applications can be created using this algorithm, just like the NSGA II algorithm with Wallacei (Makki et al., 2018) plug-in. Moreover, these apps can be used in the participatory decision- making process.

This tool can merge the needs of agents and potentials of space in a very short time and low cost, and this capability is today realised today in many urban related fields. Collaboration of artificial intelligence, generative design and urban planning is auspicious promising for fast- changing and highly demanding urban places; it is expected to see the implementations of these technological tools in the real world so soon.

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