ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

EMERGENCY AND TERMINATED EVACUATION OF WAREHOUSE BY DIJKSTRA'S ALGORITHM

M.Sc. THESIS

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Department of Geomatics Engineering

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

DIJKSTRA ALGORİTMASI KULLANILARAK ACİL VE SINIRLANDIRILMIŞ DEPO TAHLİYESİ

YÜKSEK LİSANS TEZİ

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Deniz Doğa IŞIK, a M.Sc student of İTU Graduate School student ID 501211611, successfully defended the thesis/dissertation entitled "EMERGENCY AND TERMINATED EVACUATION OF WAREHOUSE BY DIJKSTRA'S ALGORITHM", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my dear family and all of my dear friends who support me tirelessly,

FOREWORD

First of all, I would like to thank my thesis advisor Asst. Prof. Şaziye Özge Atik, who always helped me without hesitation during the thesis study process. I would also like to thank my beloved family who always supported me financially and morally throughout my engineering education.

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ABBREVIATIONS

GIS	: Geographic Information Systems
QGIS	: Quantum GIS
TSP	: Traveling Salesman Problem
IoT	: Internet of Things
CAD	: Computer Aided Design
TUREF	: Turkish National Reference Frame
TM30	: Transverse Mercator 30 Degree
QR	: Quick Response
GNSS	: Global Navigation Satellite Systems
IPS	: Indoor Positioning Systems
UW	: Ultrawide
RFID	: Radio Frequency Identification
NFC	: Near Field Communication
WLAN	: Wireless Local Area Network
BT	: Bluetooth
IR	: Infrared
Wi - Fi	: Wireless Fidelity
SLAM	: Simultaneous Localization and Mapping
IEEE	: Institute of Electrical and Electronics Engineers
RSSI	: Received Signal Strength Indicator
IMU	: Inertial Measurement Unit
OSM	: OpenStreetMap
2D	: 2-Dimensonal
3D	: 3-Dimensonal
UML	: Unified Modeling Language
ER	: Entity Relationship
DBMS	: Database Management System
SQL	: Structured Query Language
BFS	: Breadth First Search
IFC	: Industry Foundation Classes

2.5D **:** 2.5-Dimensonal

LBS **:** Location Based Services

IPS **:** Indoor Positioning Systems

SYMBOLS

D	**:** Set of Nodes
K	**:** Set of Edges
G	**:** Graph

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EMERGENCY AND TERMINATED EVACUATION OF WAREHOUSE BY DIJKSTRA'S ALGORITHM

SUMMARY

One of the most important services that developing technology has brought to humanity and that serves as a facilitator in daily life has been navigation services. Thanks to location services, millions of people can easily reach the point they want to reach in daily life, and their industrial impact has also become an indisputable advantage. In addition to location information obtained through GNSS, technological developments now support location-based data and information production in indoor spaces. Here too, it is noticeable that indoor navigation maps are increasingly covering a wider area as it is getting closer to the present day. Indoor navigation maps are taking firm steps towards becoming one of the most effective facilitators that the internet age has brought to humanity. In this progression, its main areas of use stand out in megastructures such as shopping malls, university campuses, business campuses, museums, multi-storey buildings, warehouses, which accommodate many places and people that serve more than one purpose. Today, thanks to the widespread use of IoT and ease of use by the end user, indoor navigation solutions have gained an important place, especially in all kinds of loading and unloading scenarios of warehouses.

However, earthquake safety has become a very prominent topic in our country, especially after the February 6 Maraş earthquakes. Living and working in earthquake-safe buildings should be seen as a fundamental right for all humanity. At this point, the emergency evacuation of a supermarket warehouse measuring hundreds of square meters, which has been determined to be earthquake unsafe, should be re-planned beyond the standard procedure. It will be one of the best examples of indoor navigation solutions for evacuating the warehouse and ensuring the safety of employees in this emergency scenario through Geographic Information Systems (GIS) using two-dimensional floor plans. Evaluating the end-to-end usage parameters of the warehouse in order to decide not only the shortest route but also the fastest and safest option in routing the mobility in the space will be an important criterion for creating the most appropriate evacuation scenarios.

In any emergency scenario, a scenario designed only for the evacuation of the location will not be sufficient. At this point, it stands out that the evacuation from the dangerous place must be delivered to the distribution points as soon as possible. The delivery of medicines in a pharmaceutical warehouse that has been determined to be earthquake-insecure to the pharmacies in the affected area in the fastest and safest way can be arranged using location-based services.

Dijkstra's Algorithm, which forms the basis of many researches when it comes to routing and shapes the working logic of GIS programs, was also used in this study. In particular, the necessity of stopping at more than one stop in creating the evacuation scenario and the necessity of fulfilling this obligation within safe borders exactly coincide with the framework of the Algorithm.

The problem that stands out in the fictions created is defined as TSP and many different methods have been tried to solve it, and these methods continue to be developed. Starting from this point, the applications were completed in the supermarket warehouse setting by performing network analyzes in the QGIS environment, which stands out with its ease of access thanks to its free software, through indoor navigation. For the same warehouse, stops were detected by running analysis in ESRI ArcMap environment, again based on Dijktra's Algorithm. In this way, it was possible to make alternative observations. Subsequently, for the pharmaceutical warehouse evacuation, a scenario involving the pharmacies of the European Side of Istanbul was created and the shortest route was created in the ArcMap environment. The results of the thesis study were evaluated in two stages. The routes obtained for the supermarket warehouse were interpreted depending on the different examples seen during the research and the variability of the usage areas of indoor navigation. In pharmaceutical warehouse evacuation, evaluations were completed for safety and cost issues via a single route. From a broad perspective, the results of the algorithms and analyzes used to solve the TSP are associated with facility management.

DIJKSTRA ALGORİTMASI KULLANILARAK ACİL VE SINIRLANDIRILMIŞ DEPO TAHLİYESİ

ÖZET

Gelişen teknolojinin insanlığa kazandırdığı ve günlük hayatta kolaylaştırıcı bir rol oynayan en önemli hizmetlerden biri navigasyon hizmetleri olmuştur. Konum servisleri sayesinde milyonlarca insan günlük hayatta varmak istediği noktaya kolaylıkla ulaşabilmektedir, aynı zamanda bu servislerin endüstriyel etkisi de tartışılmaz bir avantaj haline gelmiştir. GNSS aracılığıyla elde edilen konum bilgilerinin yanı sıra, teknolojik gelişmeler artık kapalı alanlarda konum bazlı veri ve bilgi üretimini de desteklemektedir. Son yıllarda, iç mekan navigasyon haritalarının kullanım alanı giderek genişlemekte ve bu haritalar internet çağının sunduğu en etkili kolaylaştırıcılardan biri olma yolunda hızla ilerlemektedir. İç mekan navigasyon haritalarının başlıca kullanım alanları arasında alışveriş merkezleri, üniversite kampüsleri, iş yerleşkeleri, müzeler, çok katlı binalar ve depolar gibi, birden fazla amaca hizmet eden ve çok sayıda insanı barındıran mega yapılar bulunmaktadır.

Nesnelerin İnterneti'nin (IoT) yaygınlaşması ve son kullanıcı tarafından kolaylıkla kullanılabilmesi, iç mekan navigasyon çözümlerinin özellikle depolarda her türlü yükleme ve boşaltma senaryosunda önemli bir yer edinmesini sağlamıştır. Ancak ülkemizde, özellikle 6 Şubat Maraş depreminden sonra, deprem güvenliği öncelikli bir konu haline gelmiştir. Depreme dayanıklı binalarda yaşamak ve çalışmak, tüm insanlığın temel hakkı olarak görülmelidir. Bu bağlamda, depreme dayanıklı olmadığı belirlenen yüzlerce metrekarelik bir süpermarket deposunun acil tahliyesi, standart prosedürlerin ötesinde yeniden planlanmalıdır. Kapalı alanda yapılacak bir çalışmaya ek olarak, herhangi bir kapalı mekanın içerisindeki tahliye senaryolarının kurgusunun ardından; çıkışı yapılacak ürünlerin en hızlı ve güvenli şekilde varış noktalarına ulaştırılması da büyük önem taşımaktadır. Deprem dayanıklı olmadığı tespit edilen bir ecza deposunda bulunan ilaçların İstanbul Avrupa Yakası'ndaki belirli eczanelere dağıtılması için de GNSS servislerinden destek alınarak rota planlaması yapılabilecektir.

İki boyutlu kat planları kullanılarak Coğrafi Bilgi Sistemleri (CBS) aracılığıyla, acil durum senaryolarında deponun boşaltılması ve çalışanların güvenliğinin sağlanması, iç mekan navigasyon çözümlerinin en güzel örneklerinden biri olacaktır. Alandaki hareketliliğin yönlendirilmesinde sadece en kısa rotaya değil, aynı zamanda en hızlı ve en güvenli seçeneğe karar vermek için deponun uçtan uca kullanım parametrelerinin değerlendirilmesi, en uygun tahliye senaryolarının oluşturulmasında önemli bir kriter olacaktır. Konum bazlı servislerden elde edilecek veri ve bu verilerden üretilecek bilgi sayesinde, yine personel güvenliği gözetilerek optimal rota oluşturulabilir.

Yönlendirme konusunda birçok araştırmaya temel oluşturan ve CBS programlarının çalışma mantığını şekillendiren Dijkstra Algoritması bu çalışmada da kullanılmıştır. Özellikle tahliye senaryosunun oluşturulmasında, birden fazla durakta durma zorunluluğu ve bu yükümlülüğün güvenli sınırlar içerisinde yerine getirilmesi gerekliliği, algoritmanın çerçevesiyle birebir örtüşmektedir. Bu noktadan hareketle, ilk aşamada ücretsiz yazılımı sayesinde erişim kolaylığıyla ön plana çıkan QGIS ortamında ağ analizleri yapılarak, kurgunun en etkin şekilde şekillendirilmesi konusunda uygulamalar tamamlanmıştır. Tez çalışmasının sonuçları, araştırma sırasında incelenen farklı örneklere ve bina içi navigasyonun kullanım alanlarının değişkenliğine bağlı olarak yorumlanmıştır. Diğer uygulamada ise ArcMap kullanılarak yine iç mekan navigasyon uygulama örneği destekleyici bir çalışma olarak eklenmiştir. ModelBuilder kullanılarak rota katmanı oluşturulmuş ve durakların tespiti yapılmıştır. Devamında, yine ModelBuilder kullanılarak ecza deposunun boşaltılmasının ardından dağıtıcının eczanelere ulaşacağı rota oluşturulmuştur.
Depo tahliyesi iç mekan navigasyonunda kullanılan veriler, bir süpermarket deposunun iki boyutlu kat planlarını içerir. Kat planları iki boyutlu olarak tasarlanmıştır ve verilere herhangi bir Z değeri dahil edilmemiştir. Tüm veriler CAD formatından CBS ortamına aktarılırken TUREF TM30 Projelendirilmiş Koordinat Sisteminde olmasına dikkat edilmiştir. Tüm analizler ve yorumlamalar da yine TM30 koordinat sisteminde gerçekleştirilmiştir. TUREF TM30'un seçilmesinin ana nedeni, deponun konumlandığı İstanbul şehri için koordinat sisteminin uygun olduğu görüşüdür. Çalışmada yersel ölçme verileri kullanılmamıştır, çünkü CAD verilerinden alınan ölçüler tezin kapsamını yerine getirmek için yeterlidir. Çalışma ortamı tamamen deponun kendi dinamikleriyle sınırlı olduğu için, tüm işlemler kendi içinde tutarlı ve ölçülerin elde edilme şekli dolayısıyla yüksek doğruluk düzeyine sahip olacağı öngörülmüş olup sonuçlarla da desteklenmiştir.
Bu çalışmada kullanılan katmanlar, tüm depo içeriğinden özelleştirilmiştir ve kat planları CAD verilerinden sayısallaştırılmıştır. Çünkü acil durum tahliye planı, depoda bulunan ve boşaltılması gereken hızlı tüketim ürünlerini dikkate almaktadır. Katmanlara gelinecek olduğunda, Points katmanı giriş ve çıkış noktalarını, ürün sarım alanlarını, kapıları ve Bread, Fru-Veg, Meat-Chk, Cold ve Frozen katmanları ilgili ürünlerin bulunduğu rafları temsil eder. Koridorları gösteren Segments katmanı ve tüm yürüyüş yollarını içeren Levels katmanı kullanılmıştır. Son olarak, mekanın haritalanması, Polygons katmanı kullanılarak raflar ve belirli alanların (Sarım alanları poligonlarla sınırlandırılarak noktalar ile de tanımlanmıştır.) sınırlandırılmasıyla tamamlanmıştır.
Ecza deposunun tahliyesi için kullanılan veriler ise OpenStreetMap üzerinden elde edilmiştir, açık bir veri olması sebebiyle araştırmaların genişletilmesi açısından son derece önemlidir. Çalışma yine TUREF TM30 üzerinden yürütülmüş olup yükseklik yani Z değerleri göz önünde bulundurulmamıştır. Katmanlar eczaneleri temsil eden Pharmacies, ilçeleri temsil eden Urban_Points ve yolları temsil eden Roads ile isimlendirilmiştir.
Çalışma eczanelerin ilçelerle eşleştirilmesiyle başlatılmış ve devamında eczanelerin ilçe bazlı olarak orta noktaları tespit edilerek rota katmanı oluşturulmuştur. Buradan elde edilen çalışma katmanı aracılığıyla eczaneler arasındaki en kısa rota ModelBuilder aracı kullanılarak elde edilmiştir.

İlk çalışmanın sonuçları, iç mekan navigasyon sistemlerinin özellikle acil durum senaryolarında, depreme dayanıklı olmayan binaların tahliyesinde ne kadar hayati bir rol oynadığını göstermektedir. CBS ve Dijkstra Algoritması'nın etkin kullanımı, bu tür senaryolarda en hızlı ve güvenli tahliye rotalarının belirlenmesinde kritik bir öneme sahiptir. Bu bağlamda, araştırma, iç mekan navigasyon çözümlerinin güvenlik ve etkinlik açısından nasıl optimize edilebileceğine dair önemli katkılar sağlamaktadır. Gelecekteki araştırmalar, bu entegrasyonların daha da geliştirilmesine ve farklı acil durum senaryolarında uygulanabilirliğinin artırılmasına odaklanmalıdır. Böylece, navigasyon çözümlerinin günlük operasyonel verimliliği artırmanın yanı sıra, acil durumlarda da kritik bir güvenlik unsuru olarak işlev görmesi sağlanacaktır.
İkinci çalışmada ise GNSS verileriyle desteklenen konum bilgilerinden üretilen rota ile yine bir acil durum senaryosunda yapılacak olan tahliyenin, iç mekanın boşaltılmasının ardından en hızlı şekilde nasıl kurgulanabileceği anlaşılmıştır.
Çalışmalar, Gezgin Satıcı Problemi (GSP) üzerinden yapılandırılmıştır ve odak noktası, acilen boşaltılması gereken bir depodaki hızlı tüketim ürünlerinin öncelikli olarak nasıl tahliye edileceğidir. Bu bağlamda, ürünlerin depo içerisindeki konumları bilinerek en kısa mesafeyle ve en düşük maliyetli şekilde güvenli çıkışa yönlendirilmesi araştırılmıştır. İnsan gücüyle yapılacak tahliyede, çalışanların depo içerisindeki konumlarını belirleyebilmeleri için QR kodlar kullanılabilir. Ancak, her raf için ayrı QR kod yerleştirmenin ekonomik olmayacağı düşünülerek, rotalamada topolojik ilişki ve yakınlık esas alınmıştır. Konum servislerinin kullanılabildiği versiyonda ise doğrudan bir online navigasyon aplikasyonunda uğranılmak istenen duraklar eklenerek rota takip edilebilecektir. Çalışmalar, GSP'nin çözümünü Dijkstra Algoritması ile birleştirerek ele almıştır. Uygulama, durakların düğümler olarak tanımlanması ve bu düğümlerin kenarlarla birbirine bağlanarak rotaların oluşturulmasına dayanmaktadır.
Projenin Dijkstra Algoritması üzerine kurgulanmış olması sebebiyle bu algoritma üzerine yazılan bir kod veya bir program aracılığıyla ortaya koyan bir uygulamayı gerektiren rotalamaya odaklanmaktadır. Analizler, maliyetleri ve depo trafiğini azaltmak için minimum sayıda yolculukla kaydedilen en kısa mesafeyi hedefleyerek bir ürün tipinin boşaltma noktasına hızlı bir şekilde teslim edilmesine odaklanmıştır. Bu noktada işçi sağlığı ve iş güvenliği hususunda da en etkili çalışmanın yapılması hedefi için ilerleme kaydedilmiştir. Süpermarket deposu örneğinde beş ürün grubu incelenmiştir ve her biri için farklı sonuçlar elde edilmiştir. QGIS üzerinde Ağ Analizi aracında yer alan "En Kısa Yol (Noktadan Noktaya)" analizi, standart olarak 10 metreye ayarlanan topoloji toleransı ile her ürün grubu için ayrı ayrı uygulanmıştır. Bu topolojik tolerans, kapalı bir alanda GNSS sinyalleri olmadan konum bilgisine ulaşma esnasında hata aralığını azaltmak amacıyla belirlenmiştir. Nesneler arasındaki topolojik ilişkiyi anlamak, tolerans belirlenmesi ve analizlerin sağlıklı çalışabilmesi açısından da önemini gözler önüne sermiştir. GNSS sinyallerinin kullanılabildiği ecza deposu örneğinde de yine topolojik ilişkiler önem taşımaktadır. Ancak burada önem arz eden nokta, eczanelerin ilçeleriyle topolojik olarak eşleştirilmesine dayanmaktadır. Tahliyede, ArcMap üzerinde "Mekansal Analiz Aracı" kullanılmış olup ilişkiler kurulmuştur. İlçe bazlı olarak birbirine en yakın olan ve orta noktaları tespit edilen eczaneler için optimum rotada, tahliye birkaç lokasyon için tek bir durak kurgulanmasıyla oluşturulmuştur.

Çalışmada kullanılan yöntem, verilerin toplanmasından itibaren nokta, çizgi ve poligon sınıflarıyla tanımlanmasını gerektirir. Algoritma, poligonların düğümlerin bir parçası olup olmadığını değerlendirerek mesafe ve maliyet açısından farklılıklar yaratabilir. Başlangıç ve bitiş noktalarının tanımlanması zorunludur; bu noktalar koordinatları ile belirlenir ve graf içinde ayrışır. Algoritma, başlangıç noktasından en yakın düğümü tespit ederek en kısa yolu oluşturur, ancak her durumda en yakındaki nokta en kısa mesafe anlamına gelmeyebilir. Algoritma, veri tabanından elde edilen mesafe bilgilerini kullanarak en uygun kararı verir.

Süpermarket deposunda analizler, bir ürün tipinin en hızlı şekilde tahliye noktasına ulaştırılması üzerine odaklanmıştır. En kısa mesafenin minimum sefer sayısıyla elde edilmesi, maliyeti azaltırken depo içi trafiği de minimize eder. Beş farklı ürün grubu için yapılan analizlerde farklı sonuçlar elde edilmiştir. QGIS üzerindeki "En Kısa Yol (Noktadan Noktaya)” analizi, 10 metre topoloji toleransı ile gerçekleştirilmiştir. Yolculuk hızı saatte 5 km olarak belirlenmiş ve iş sağlığı ile güvenliği dikkate alınmıştır. Rota oluşturulacak katmanlarda "Direction Field" özniteliği kullanılarak koridorlar ve bağlantılar sınırlandırılmıştır.

Her katman için yapılan analizlerde, ikiden fazla raf sırası olan ürünler için birden fazla rota üretilmiş ve en kısa optimal sonuç elde edilmeye çalışılmıştır. Bu yöntem alternatif çözümler üreterek çalışmanın zenginleştirilmesini sağlamıştır. Rotalar benzer görünse de, her rotanın toplam mesafesi farklı olup, bu durum maliyet analizinde de kullanılmıştır.

Analizlerin tamamlanmasının ardından her bir ürün grubu için elde edilen rotalarda mesafeler temel çıktı olarak alınmaktadır. Buradan elde edilen mesafe verileri ile birlikte metadata olarak mevcutta bulunan raf boşaltma süresi ve forklift sayıları kullanılarak maliyet analizi tamamlanmıştır. Ürün bazlı tahliye başına hesaplanan süreler ile kullanılan forklift sayısına bağlı yakıt tüketiminden yola çıkılarak yapılan bu maliyet analizi, elbette personelin güvenliğinin de dikkate alındığı sınırlar içerisinde gerçekleştirilmiştir.

Maliyet analizine ek olarak, ağırlık tablosu da hazırlanarak bu hesaplamaya en çok etki eden kriterlerin üzerinde durulmuştur. Kriterlerin birbirine etkisine bağlı olarak, işlem sürelerinin bu çalışmada da etkisinin bir hayli yüksek olduğu gözlenmiştir.

QGIS üzerinden yapılan uygulamanın ardından, GSP’nin farklı bir çözümlenmesinin yapılabilmesi adına ESRI ürünü olan ArcMap ile de uygulama çeşitlendirilmiştir. Burada, her bir katman için ayrı ayrı ve tüm duraklara ayrı ayrı uğranması üzerine bir senaryo kurgulanmış olup analizler ModelBuilder üzerinden yürütülmüştür. Alternatiflerin gözlenebildiği bu çalışmada, analiz işlem adımları mevcut veri ile gösterilmiş olup senaryo, farklı bir veriseti ile de desteklenerek programın çözümlemeyi nasıl tamamlandığının anlaşılabilmesi adına yine tez kapsamında sunulmuştur.

Ecza deposu için kurgulanan senaryoda ise, eldeki veriler aracılığıyla herhangi bir hiyerarşi ve kısıtlama kullanılmaksızın durakların birbirine olan uzaklığı kıstas alınarak rotanın oluşturulması planlanmıştır. Dijktra Algoritması’nın temel mantığı çerçevesinde bu planlama uygulamaya alınmıştır. Halihazırda rota katmanı süpermarket örneğindeki gibi bir tane olmasına rağmen burada duraklar da tek bir katmanla gösterilebildiği için tek bir rota oluşturulmasında herhangi bir sakınca görülmemiştir.

Maliyet analizi ise kilometre başına tüketilen yakıta dayandırılmış olup hesaplama da yine bu iki temel başlık içinde değerlendirilmiştir. Son aşamaya gelindiğinde; toplam süre, kat edilen yol ve burada tüketilecek yakıt ile maliyet analizi tamamlanmıştır.

Çalışmanın sonuna gelindiğinde lojistik ekipman kapasitesinin değiştirilemediği durumlarda algoritmadan elde edilen analiz sonuçları tesis yönetimi verileriyle desteklendiğinde zaman ve maliyetin lokasyon bazlı değerlendirme sürecine göre farklı şekilde birbirini tetiklediği görülmektedir. Bu durumda algoritma oluşturulurken tesis yönetim verilerinin dahil edileceği endüstriyel yönlendirme sistemlerinin yeni yaklaşımlarla geliştirilmesine yönelik çalışmaların gerekliliği ortaya çıkmaktadır.
Depo optimizasyon çözümlerinin mevcut araştırma ve kullanımının sunduğu alternatiflerin ötesine nasıl geçebileceği konusunda bir sonuca varmak için üzerinde durulan soruların yanıtlanması gerekmektedir. Acil durumlarda alternatiflere açıklık eksikliği ile karşı karşıya kalınabileceğinden, "en kısa yol" için üretilecek herhangi bir çözümün algoritma ve yönlendirmeler çerçevesinde sınırlamalara tabi olması kaçınılmazdır. Güvenliğin öncelikli olduğu çözümler için CBS ortamında üretilen bilgilerin yerleşim, mimari ve lojistikte etkin bir şekilde kullanılması gerekmektedir.

1. INTRODUCTION

1.1 Aim And Scope

From past to present, humanity's effort to make its actions continuous and easy in every process has deeply affected the development of technology. Indoor and outdoor navigation systems have been one of the best examples of this. Although direction finding and routing activities can be easily carried out outdoors with the help of GNSS systems, processes that need to be supported by supporting hardware and different algorithms for positioning indoors emerge. To localize an object or place, it is important to determine its position in relation to the surrounding objects. Typically, while positioning outside, cartographic maps of the surrounding region are employed. However, for interior objects, maps comparable to Fire Evacuation Plans might be a viable choice [1]. Today, thanks to the widespread use of Internet of Things (IoT) and ease of use by the end user, indoor navigation solutions have gained an important place in warehouse optimization. In the Internet of Things paradigm, objects are equipped with the ability to see their surroundings and communicate with one other in order to interact with their environment. In contemporary IoT methodologies, the things linked to the internet are everyday objects wih integrated sensors. The IoT solutions generate vast amounts of data that may be utilized for making informed decisions [2]. At this point, it becomes necessary to produce indoor navigation solutions with different alternatives in large spaces such as warehouses, where location/direction determination may become difficult depending on the location. The real-time IPS should be easier to deploy, more accurate, affordable, scalable, reliable, and need less computational work. [3].

To elaborate on these alternatives, first of all, the place in question must be equipped with extra equipment that will provide location data and their distribution must be planned to ensure continuity of use. To enable indoor navigation, a comprehensive set of criteria must be met to consistently track the user's location within a building and direct them to their desired destination [4]. Devices such as UW Band provider beacons, RFID - NFC installation areas, WLAN - BT - IR devices are the most basic and efficient examples of hardware. Wi-Fi, Bluetooth, RFID, and computer vision are utilized to locate warehouse spaces. Each method encounters signal interference, accuracy difficulties, and expensive implementation costs. SLAM and other mapping and floorplan creation methods are essential for realistic warehouse representations. Real-time mapping and updating are difficult owing to the libraries' dynamic nature [5]. The extensive adoption of the IEEE 802.11 technology was utilized in WLAN infrastructure to address the lack of GPS location sensing, which was previously the exclusive way of indoor localization. The architecture, implemented on Android-based smartphones, primarily depends on RSSI measurements taken at different distances from the Wi-Fi access point and utilizes a database tables method. Compared to previous architectures, it provides users with enhanced performance and an improved user interface [6]. In addition, today, with QR codes, this process can be supported with a cost-effective and end-user-friendly solution. When it comes to the features of the hardware, it must run technologies such as Wi-Fi, Bluetooth and Infrared; In addition, depending on the characteristics of the system to be used, motion and acceleration-related supports such as IMU should be integrated into the system. Some studies highlight the use of IMU compared to the technologies mentioned above, which are characterized by additional hardware costs and installation difficulties. In addition to the use of QR or other location information supporting natural markers integrated into the space, as planned to be implemented in this project, it is possible to measure the end user's movement within the facility and provide effectiveness in route tracking [7]. It is evident that the location update will be initiated upon the identification of a new marker. Nevertheless, the device sensors, which include the accelerometer and compass, update the user's location when the user departs from that location, ensuring that the user has an absolute orientation. Inertial navigation is the term used to describe this method. An algorithm has been developed to determine the most optimal routes for the user to travel to their destination [8].

When the subject is specifically related to the research title of this thesis, although examples of indoor navigation being used in warehouse loading and unloading operations are known, the process of privatization of studies on this subject is still proceeding on a sample basis. For example, with existing technology and methods, it will be possible to easily implement the optimization management of a warehouse from the moment the products enter the warehouse to the moment they reach the distribution point. Utilizing this technology can assist individuals in critical situations, such as locating an emergency escape in large-scale structures or identifying the requisite department inside a hospital. In addition, the utilization of indoor navigation technology not only addresses the issue of individuals searching for specific locations, but also offers commercial advantages in terms of tracking and analyzing human behavior [9]. However, in an emergency scenario that may arise, what kind of setup should be created beyond the standard procedure will vary depending on the structure of the warehouse and product content.

Considering the Urfa and Izmir flood disasters that occurred consecutively after the February 6 Maraş earthquakes, it becomes clear that any emergency plan must be customized in such large and relatively difficult to control places. The deficiencies detected, especially regarding earthquake resistance, stand out as a serious problem of our country, and it should be noted that this issue is also evidence of the evacuation scenario at the backbone of the thesis. To comprehend the fundamental characteristics of earthquake-resistant structures, two key elements must be incorporated. Firstly, horizontal bands should be implemented at the 0, lintel, and roof levels in accordance with the prescribed code. Secondly, vertical reinforcement should be provided at critical points, including corners, internal and external wall junctions, as specified by the code [10].

In the supermarket evacuation study, research and applications were made on what kind of scenario could be used to evacuate the products that need to be evacuated first from a supermarket warehouse that was determined to be not earthquake resistant by using 2D floor plans. When considering pharmaceutical warehouse study, coordinates of the pharmacies and urban points were used to determine optimal route. Using Geographic Information Systems and network analysis, it was studied how to perform the fastest and most reliable evacuation in an optimized version of the existing settlement. Network analysis is a spatial method that uses line characteristics from geographical vector data to examine tangible connections, such as physical lines like roads and waterways, rather than virtual boundaries [11]. In the supermarket study, these physical lines are restricted with the corridors of the facility. The interior environment is defined by the existence of enclosing walls, entrances, hallways, furniture, individuals, and other mobile things. The static indoor environment is often characterized by stationary barriers present inside the landscape. The consideration was made based on the idea that the robot will only travel inside a specific area of the territory that will never be blocked by other moving items [12]. The factors affecting the "shortest path" scenario were researched and weighted, and it was aimed to create the optimal evacuation route thanks to this weighting in situations that could change instantly.

The basis of the study, together with the results obtained from the research, was the determination of the relationship between all the stops and roads that will be subject to routing. At this point, it is interpreted whether the best results can be obtained with a study supported by free software beyond the most effective known method of this relationship.

1.2 Project Flowchart

If the project flow needs to be briefly explained, after a literature review on indoor navigation and evacuation, the method of determining the criteria for the warehouse solution in question and clarifying the analysis types based on this was followed. Subsequently, the necessary data was identified and collected, and then operations such as system entries and digitizations were noted. Finally, the information generated from the processed data was also collected, and all of it was included in the thesis (Figure 1.1).

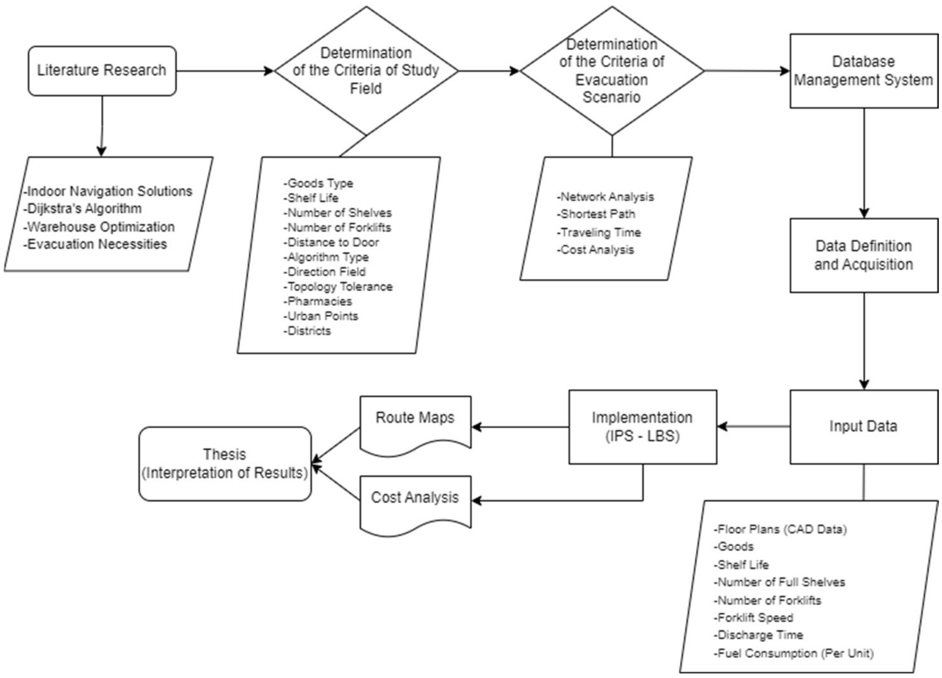

Figure 1.1 : Project flowchart.

2. MATERIALS AND METHODOLOGY

2.1 Materials

2.1.1 Supermarket warehouse

The data used in the study are 2D floor plans of a supermarket warehouse. Floor plans were prepared entirely in two dimensions and no Z value was included in the data. While all data was included in the GIS environment from CAD format, care was taken to include it in the TUREF TM30 Projected Coordinate System. All analyzes and interpretations were also completed in the TM30 coordinate system. The main reason for choosing TUREF TM30 is that the relevant slice of the coordinate system was deemed suitable for the city of Istanbul where the warehouse is located. No terrestrial measurement data was used in the study, and the measurements from CAD data were deemed sufficient within the scope of the thesis. Because the working environment is completely limited to the dynamics of the warehouse itself, all operations will be consistent within themselves and the accuracy will be high due to the way the measurements are obtained as seen in the Figure 2.1, highlighted area.

Figure 2.1 : Satellite image of the supermarket warehouse.

Floor plans were obtained from CAD data by digitization method, and the layers used in this study were customized from the entire warehouse content. Because while the emergency evacuation scenario was being designed, fast-moving consumer goods that were in the warehouse and whose unloading became a priority were included in the study. Here, there is the Points layer located in the border areas of the warehouse and indicating entry and exit points, product wrapping areas and doors, and Bread, Fru-Veg, Meat-Chk, Cold and Frozen layers representing product shelves. Of course, the Segments layer represented corridors, and the Levels layer represented all walkways. Finally, space mapping was completed by delimiting the shelves and certain regions with the Polygons layer as shown in the Figure A.1.

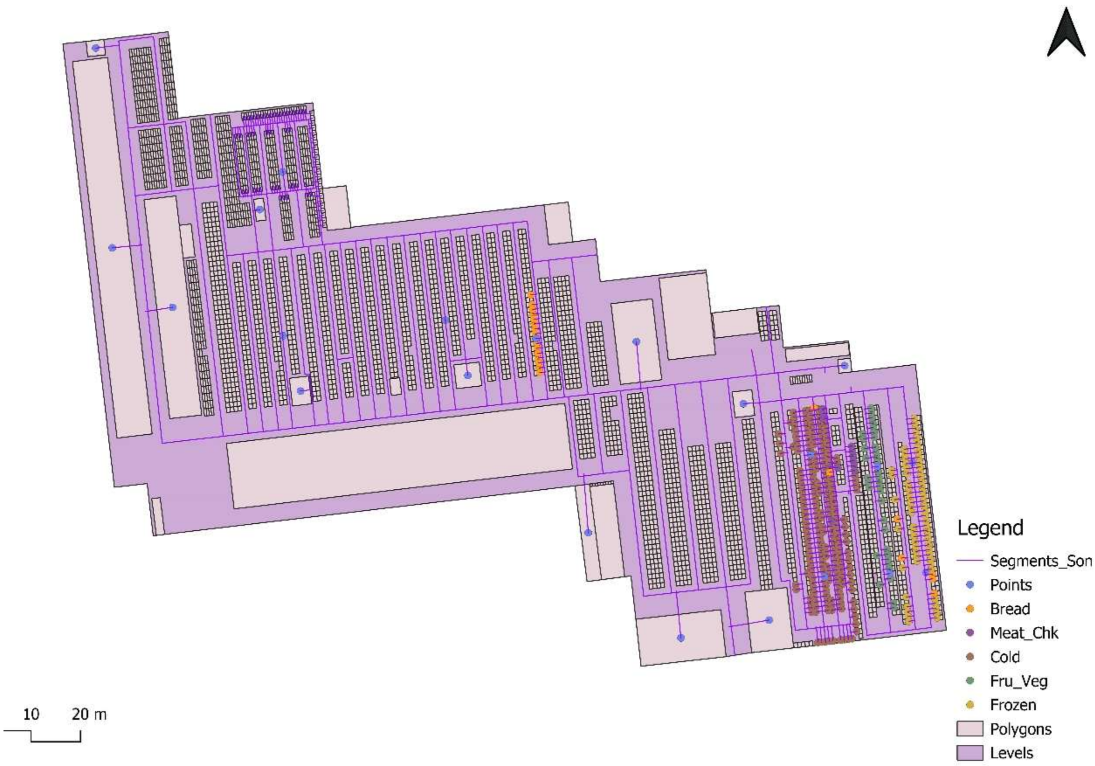

Figure A.1 : Digitized 2D floor plan on QGIS.

2.1.2 Pharmaceutical warehouse

The data obtained for the pharmaceutical warehouse was obtained through OSM and elevation (Z) values were not taken into account in this study. The data was downloaded in the WGS84 coordinate system and the processes were started by converting to TUREF TM30 at the beginning of the study. Next, layer names are arranged for the data to be used. Point layers Pharmacies, Urban_Points; The line layer is named European_Roads and the polygon layer is named European_Districts.

Pharmacies layers were used to represent pharmacies, Urban_Points to represent the areas to be used to determine delivery points, European_Roads to represent roads, and European_Districts to represent districts as seen in the Figure A.2.

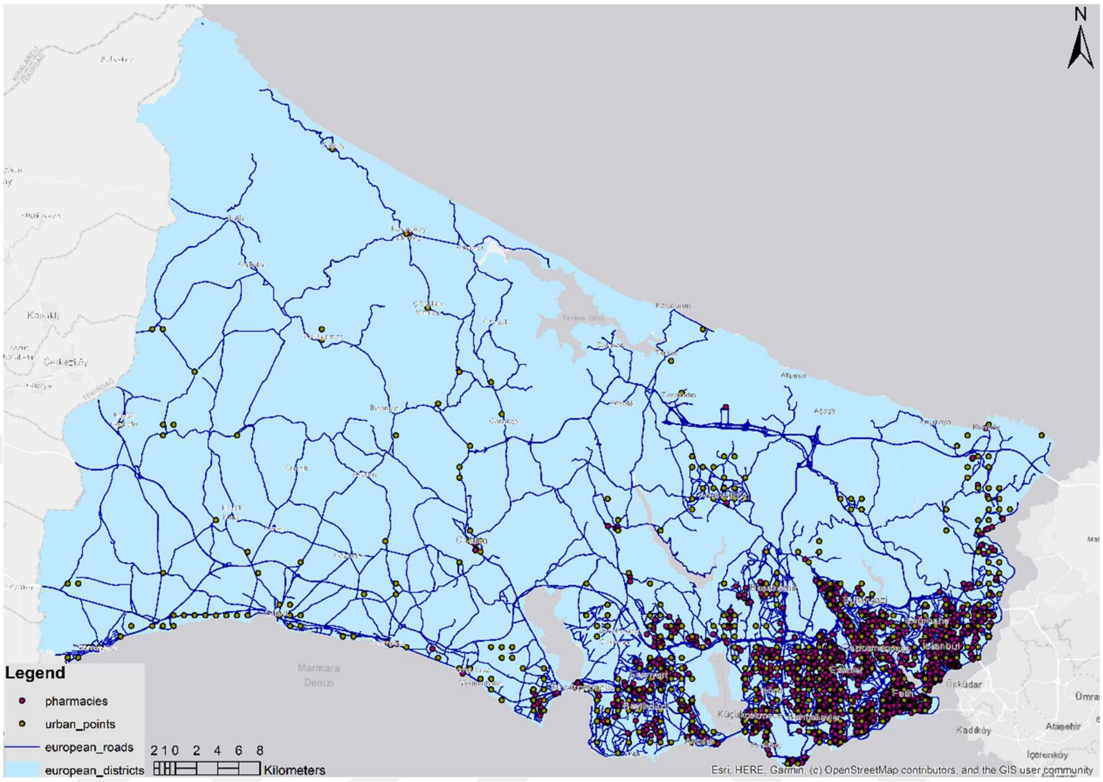

Figure A.2 : Pharmacies and urban points.

2.2 Database Management System

DBMS was created for selecting and eliminating related data by considering scope of the supermarket study. In the pharmaceutical evacuation route, related data was downloaded for the scope, thus, any elimination was not needed.

The ER diagram-relational schema (Figure 2.2) and UML diagram (Figure 3.3) of the data were also prepared. Using these relationships has an important place in explaining the relationship between line and point data during routing. Because, in addition to the methodology will be explained in the following sections, the relationships between the existing data should also be explained topologically in terms of adjacency. Otherwise, Dijkstra's Algorithm, which is the subject of the study, will fail to produce any route because it cannot establish a relationship between objects. Each point data is connected to the other in terms of proximity, with the line data forming the corridors. This was achieved by establishing the relationship by including the "segmentsId" attribute, which is the primary key of the Segments layer that forms the corridors in the database, in the point layers. In the UML diagram, relationshipd were created one to many between point layers and line layer. Each point has a corridor metadata which represents with a segmentId, and a segmentId joins more than one point feature. Relationship can be described as this basically in the DBMS.

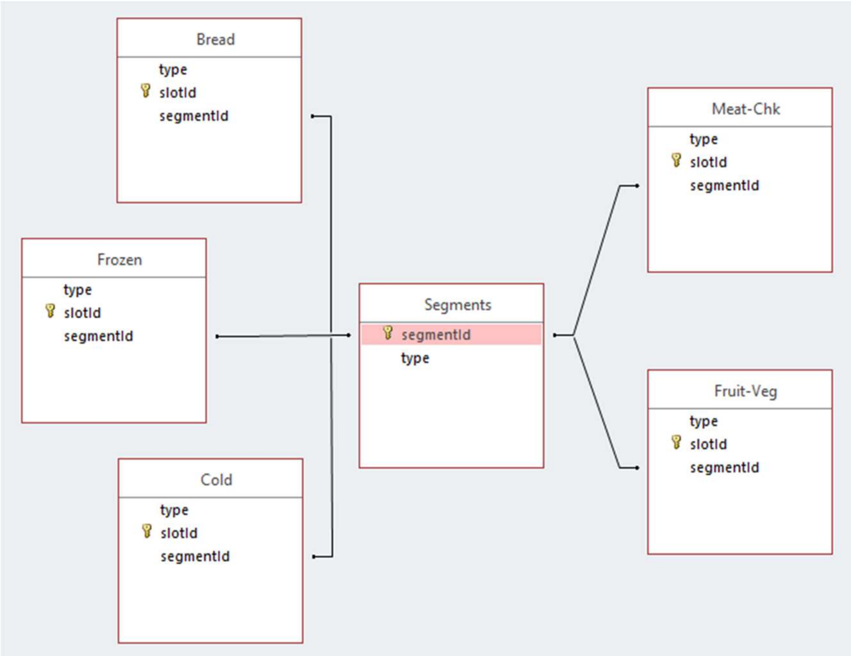

Figure 2.2 : ER diagram – relational schema.

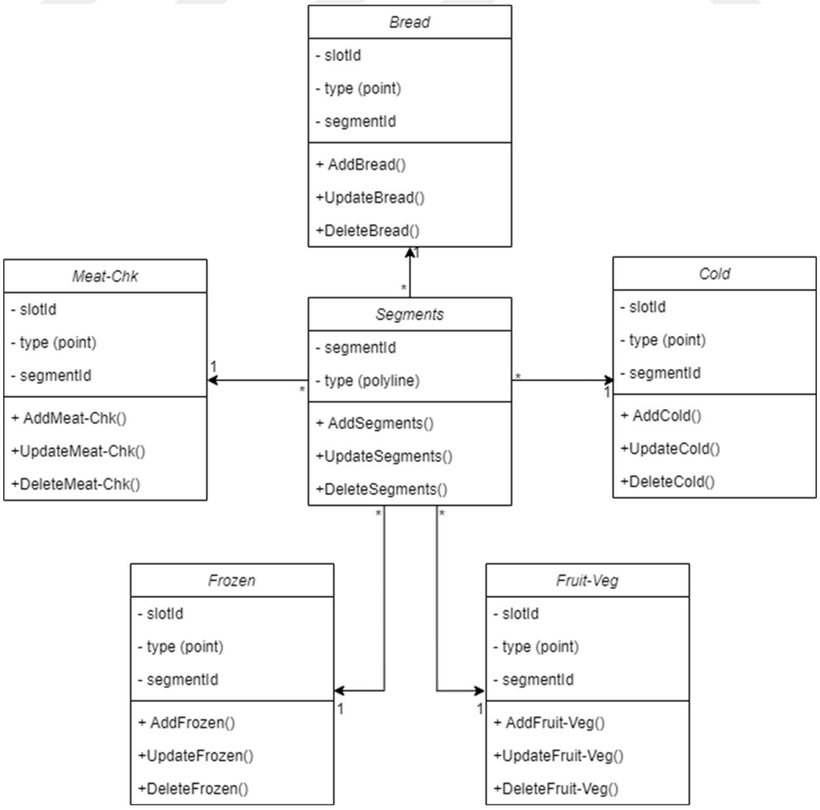

Figure 2.3 : UML diagram.

In addition to these tables, the basic queries are shown below in the DBMS. Below SQL queries were made for relating the point layer and line layer. Topological relationship between two classes can be established in this way.

SELECT Bread.segmentId, Segments.segmentId

FROM Segments INNER JOIN Bread ON Segments.segmentId = Bread.segmentId

ORDER BY Bread.segmentId, Segments.segmentId; (Figure 2.4)

Bread.segmentId	Segments.segmentI
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-038	K-038
K-059	K-059
K-066	K-066
K-066	K-066
K-067	K-067
K-067	K-067
K-067	K-067
*	

Figure 2.4 : Bread-segmentis selection by SQL.

SELECT Segments.segmentId, [Meat-Chk].segmentId

FROM Segments INNER JOIN [Meat-Chk] ON Segments.segmentId = [Meat-Chk].segmentId

ORDER BY Segments.segmentId, [Meat-Chk].segmentId; (Figure 2.5)

Segments.segmentId	Meat-Chk.segmentId
K-055	K-055
K-059	K-059
K-059	K-059
K-059	K-059
K-059	K-059
K-059	K-059
K-060	K-060
K-060	K-060
K-060	K-060
K-060	K-060
K-060	K-060
K-060	K-060
*	

Figure 2.5 : Meat-chk-segmentid selection by SQL.

2.3 Methodology

The scope and structure of the study are based on the most basic routing question and its solution, and they were carried out through TSP. The most fundamental question that was addressed was how the fast-moving consumer goods in the supermarket warehouse, which need to be emptied urgently, could be evacuated as a priority. At this point, it has been investigated how the logistics of the products, whose locations are known in the warehouse, can be directed to the exit by the employees in the shortest and most cost-effective way.

In this evacuation, which will be carried out by human power, QR codes can be used so that employees can determine their location within the warehouse. QR codes are not only the cheapest and easiest solution [13]. when thought the settlement, but also the most logical method for a building which hasn't got earthquake resistance. Since it would not be possible or economical to place a separate QR code for each shelf, it was deemed appropriate to base the topological relationship on proximity in routing. Based on this idea, a study was conducted on how to solve the TSP.

In this study, TSP was examined together with Dijkstra'a Algorithm and a solution was sought. This is an adaptation of the BFS algorithm. While BFS treats all edges in the graph as having equal weights for traversal between nodes, Dijkstra's approach has the benefit of assigning specific weights to each edge, allowing for more precise calculations [14]. Dijkstra's method, named after its discoverer E.W. Dijkstra, efficiently handles the task of determining the most concise route between a certain starting point and a desired endpoint inside a graph. The discovery has been made that it is possible to determine the shortest routes from a specified starting point to all locations inside a graph simultaneously. Consequently, this particular problem is occasionally referred to as the single-source shortest pathways problem [15]. The Dijkstra algorithm is generally acknowledged as a classic and highly efficient technique for calculating the shortest path in a network with nonnegative weights. It is considered the most optimal algorithm in theory and is extensively utilized in practice. The method ensures the global optimality of the shortest path, but there is some confusion about disadvantages with low efficiency and high temporal complexity [16].

The application is basically based on defining the stops as graphs through nodes and connecting these nodes to each other with edges to easily create routes. These point and line data are defined as node and edge, respectively, as mentioned. A node is a site where a decision is made and where two edges cross, whereas an edge is a link that connects two nodes [17].

The applied method requires data to be defined with point and line classes after collection. At the same time, polygons should also be taken into account in this application, because whether the nodes are part of the polygons or not may make a difference in terms of distance and cost when the algorithm determines the points it wants to reach. Following these definitions, it will be possible to prepare the graph by creating the node points using the algorithm. Considering that the start and end points limit the route, defining the start and end points for the algorithm is mandatory. To explain, it is expected that the starting and ending points, whose coordinates are specified, will be defined separately in the graph with this attribute and differentiated from other nodes in the function to be run with this role. For a route whose starting point is defined, the algorithm is expected to determine the closest point and prepare the route for each next stop based on the shortest distance.

The mathematical solution of the Dijkstra's Algorithm based on two equations. A basic graph G = {D, K} consists of a non-empty set D of nodes and a set of K edges that establish connections or relationships between the components in this node set, without considering their sequential order [18] which described in the equation below (2.1).

$$D = \{d0, d1, d2, \ldots, dn\text{-}1, dn\},$$
$$K = \{k0, k1, k2, \ldots, kn\text{-}1, kn\},$$
$$G = \{D, K\} \qquad (2.1)$$

However, in all cases, the closest point may not be the stop that can be reached by traveling the shortest distance. In this case, the algorithm will again decide between the distance information between points that can be obtained from the database and the threshold value which can be seen in the Figure 2.6. It should not be forgotten here that no matter how consistent the data seems before reaching this point, situations such as nodes not being detected on the graph may occur. If such a problem is encountered, the process of checking whether the graph is connected and joining unconnected components together, if necessary, can be applied. This process can be seen as a correction/improvement to the algorithm's default working logic.

```
function Dijkstra(Graph, source):
    for each vertex v in Graph:                    // Initialization
        dist[v] := infinity                        // Initial distance from source to vertex
        v is set to infinite
        previous[v] := undefined                   // Previous node in optimal path from
        source
    dist[source] := 0                              // Distance from source to source
    Q := the set of all nodes in Graph             // All nodes in the graph are unoptimized
    - thus are in Q
    while Q is not empty:                          // Main loop
        u := node in Q with smallest dist[ ]
        remove u from Q
        for each neighbor v of u:                  // Where v has not yet been removed from
        Q.
            alt := dist[u] + dist_between(u, v)
            if alt < dist[v]                       // Relax (u,v)
                dist[v] := alt
                previous[v] := u
    return previous[ ]
```

Figure 2.6 : Pseudocode of Dijktra’s Algorithm.

Following this development, a route based on the shortest distance can be created. To summarize; The starting and ending points are defined, the stopping points are defined as nodes for a certain journey, and the graph is created through the edges to be created between the nodes. Given the established dimensions of the interior environment, it is possible to ascertain the distance between the nodes. Consequently, it is possible to establish weighted connections between these nodes based on the path connecting them [19]. The solution sought for the TSP should be considered as a route drawn by visiting the desired nodes and through the created edges [20] that seems in the Figure 2.7.

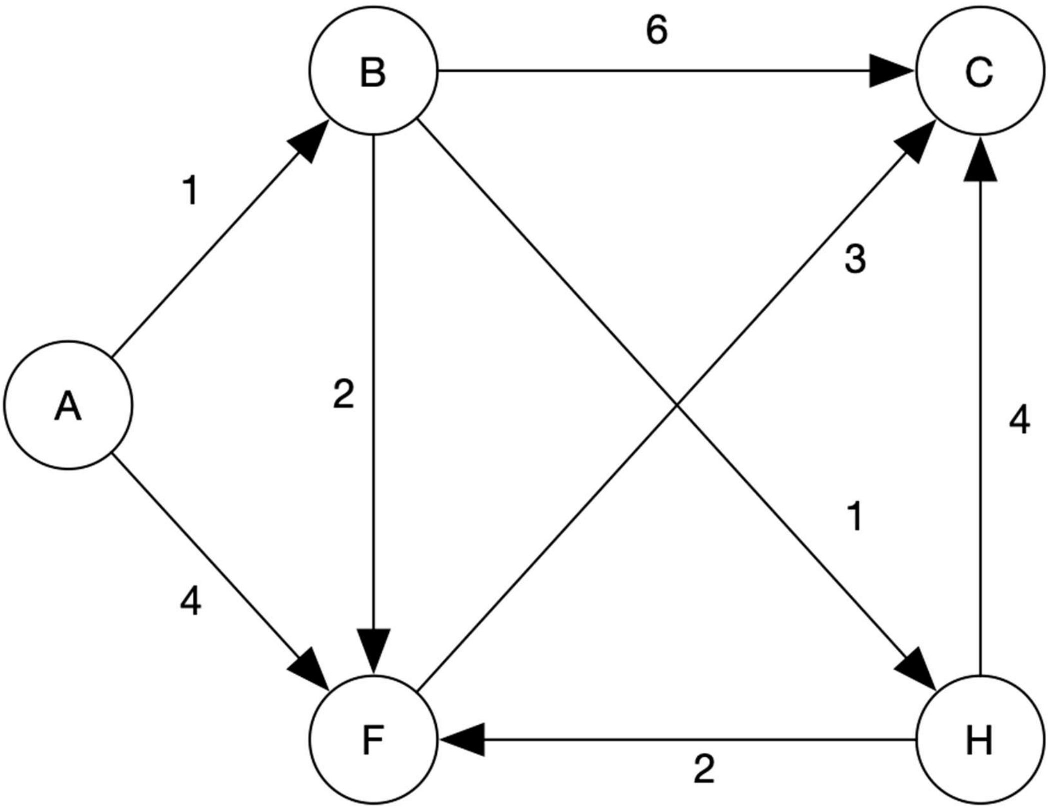

Figure 2.7 : Graph: nodes and edges.

The most critical role of the graph is to determine whether there is an edge between the desired stops. The critical part arises at the point where the graph cannot be created if a result is obtained that is not mathematically supported by the algorithm designed or written between the stops. And this; The routing may indicate restrictions in the planned area and extremely disadvantageous options in terms of time or distance. Therefore, it will be important to form nodes and edges in the most accurate way and to be able to support them with different alternatives. When explained mathematically in its simplest form, the algorithm can be described as: This ontology utilizes Dijkstra's Algorithm to do path finding inside the same level. Dijkstra's Algorithm is widely employed in solving typical shortest path seeking problems. The node coordinate using the horizontal coordinate system are specified as x and y. These values may be utilized to compute the distance between two adjacent nodes. The equation below (2.2) shows calculation of the distance between two points in simplest way [21]:

$$Distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{2.2}$$

The way the algorithm works can be explained in its simplest form as follows: The distance between the detected nodes is determined by the equation given above and the edges are drawn. This again points to the graph mentioned. After this point, the algorithm performs an analysis within the resulting graph and selects the shortest possible path. When selecting the shortest path, existing restriction and hierarchy rules are taken into account. Here, in addition to the rules, the allowed turns and the established topological relations are also important. If an explanation wanted to be carried out through the example graph, in a scenario where reaching from point A point C, if there is no restriction or hierarchy, should first proceed to point B (weighted length expressed as 1), then point F (weighted length expressed as 2) and finally point C. (Weighted length expressed as 3) As a result, the route will be completed by covering a weighted distance of 6 units. While there are no specific limitations or benefits, the selection of the route could vary if there are variations in slope around the boundaries of the same length unit.

3. WAREHOUSE EVACUATION IMPLEMENTATION

3.1 Local Based Spatial Analyzes

3.1.1 Spatial analysis by using point to point tool

Since the method focuses on routing within the scope of Dijkstra's Algorithm, the application will need to be written on this algorithm or implemented through a program. At this point, the analyzes were completed through the QGIS application, which is open source and therefore based on free software. In this study, the importance of open source software also emerges, as it is aimed to produce the solution in the easiest way in case of an emergency. Because it is accessible to everyone and has an environment nourished by the contributions of users; QGIS was seen as the most suitable option during project implementations.

The analyzes are basically based on how to deliver a product type to the discharge point as quickly as possible. The main feature taken into consideration here is that the shortest distance is recorded at the same time with the minimum number of trips. Because this will both reduce the cost and is an important solution to keep the traffic in the warehouse at a minimum level.

Based on this scenario, where product-based evacuation comes to the fore, shortest distance analysis was applied separately for the five product groups to be studied, and different results were obtained in all of them. In the studies carried out with the "Shortest Path (Point to Point)" analysis in the Network Analysis tool on QGIS, the topology tolerance was set to 10 meters as standard, as mentioned in the methodology. This distance was determined as the optimal value in order to reduce the error range during the analysis in order to obtain location information without GNSS signals in a closed area. Currently, research has been done on improving the accuracy of indoor navigation maps through the use of the map-matching approach; nevertheless, as with this work, the inability to use GPS data directly for measurement presents a challenge. The issue is made worse by the fact that there are several positioning data formats available and there is no standard format for positioning data, in contrast to GPS data in indoor contexts. As a result, different researchers have employed distinct navigation model types for map matching of diverse positional data kinds [22].Understanding the topological relationship between objects is important for accuracy. Spatial entities are determined by position of objects, form, and topological relationships. Understanding these concepts is crucial for establishing spatial relationship in networks, ensuring connectivity, proximity, intersection, and membership between objects and properties [23].

Another standard value taken into account is that all journeys are 5 km per hour. Although speed is one of the most important factors in this setup, it must be said that occupational health and safety definitely comes to the fore at this point. The last standard value used when making analyzes is the attribute data to be used in the layer where the route will be created. The area in question here is defined as "Direction Field". By selecting the "type" attribute data of the Segments layer, the areas where the route will be created can be limited with corridors and point corridor connections. The log information can be seen in the Figure 3.1.

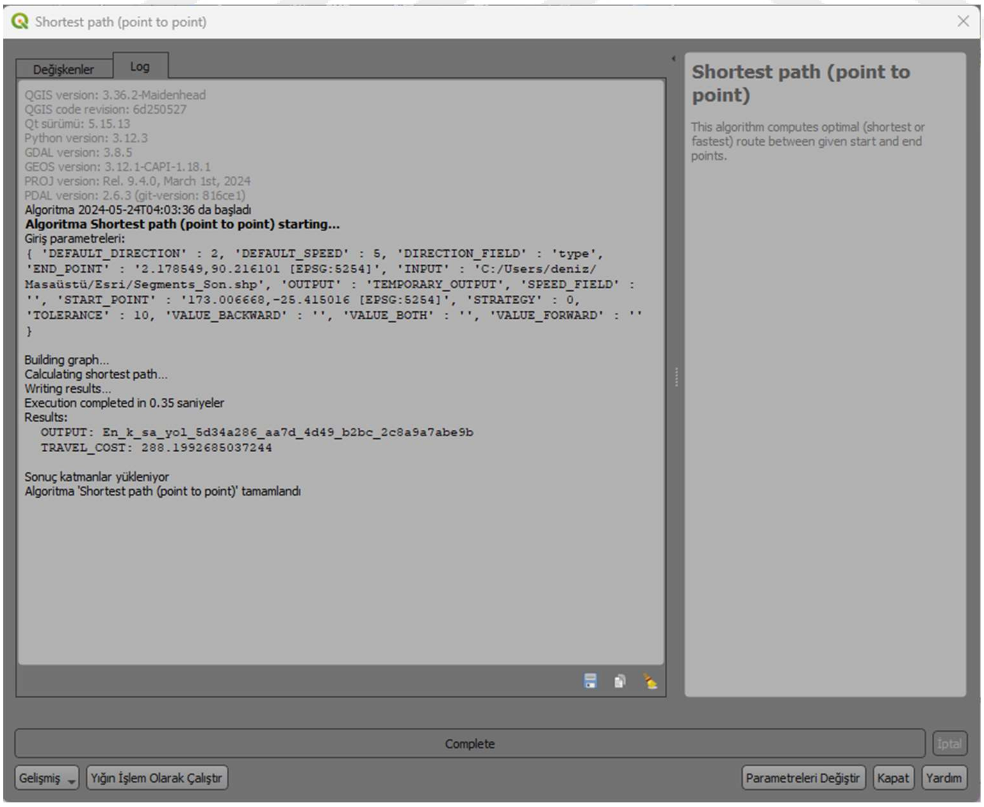

Figure 3.1 : Shortest path analysis log on QGIS.

Paying attention to these criteria, separate analyzes were run for all layers. For products with more than two opposite rows of shelves, multiple routings were produced to achieve the shortest optimal result possible. This situation also created a beneficial situation for generating alternative solutions and enriching the study. In the cost analysis, what differences this situation may create will also be discussed. Analysis results are shown in Figures 3.2-6

Figure 3.2 : Shortest path analysis result of cold.

Figure 3.3 : Shortest path analysis result of frozen.

Figure 3.4 : Shortest path analysis result of bread.

Figure 3.5 : Shortest path analysis result of fruit-veg.

Figure 3.6 : Shortest path analysis result of meat-chk.

3.1.2 Cost analysis of the supermarket warehouse

Even though the routes seem similar or close to each other, the traveling distances are different from each other. Cost analysis can also be created with the results obtained here. Although it is thought that the variability of cost results will be low due to the close travel times, the effect of the amount of stocked goods on the result can be clearly seen in the table. In the calculation, the discharge time of a shelf (5 min) multiplies is multiplied with by the maximum capacity of a forklift (20 shelves per one tour) and adds added with the travel time of the route (Travel Distance / 5 km-h). By multiplying the result obtained from this by the number of forklifts, the cost per route is obtained. Since there is no supporting data on fuel consumption in the data, the number of forklifts used in this multiplication is based entirely on the fuel consumed per unit (Table 3.1 and Figure 3.7).

Table 3.1 : Cost calculation of the route.

Routes	Travel Distance (m)	Number Of Shelves	Number Of Forklifts	Time (min.s)	Cost
Frozen_Near	275.1	10	1	53.3	53.3
Frozen_Far	288.2	58	3	103.6	310.8
Fruit-Veg	275.1	38	2	103.3	206.6
Cold_Near	273.3	113	3	278.2	834.6
Cold_Far	273.3	113	3	278.2	834.6
Meat-Chk	245.6	12	1	62.9	62.9
Bread	188.0	15	1	77.3	77.3

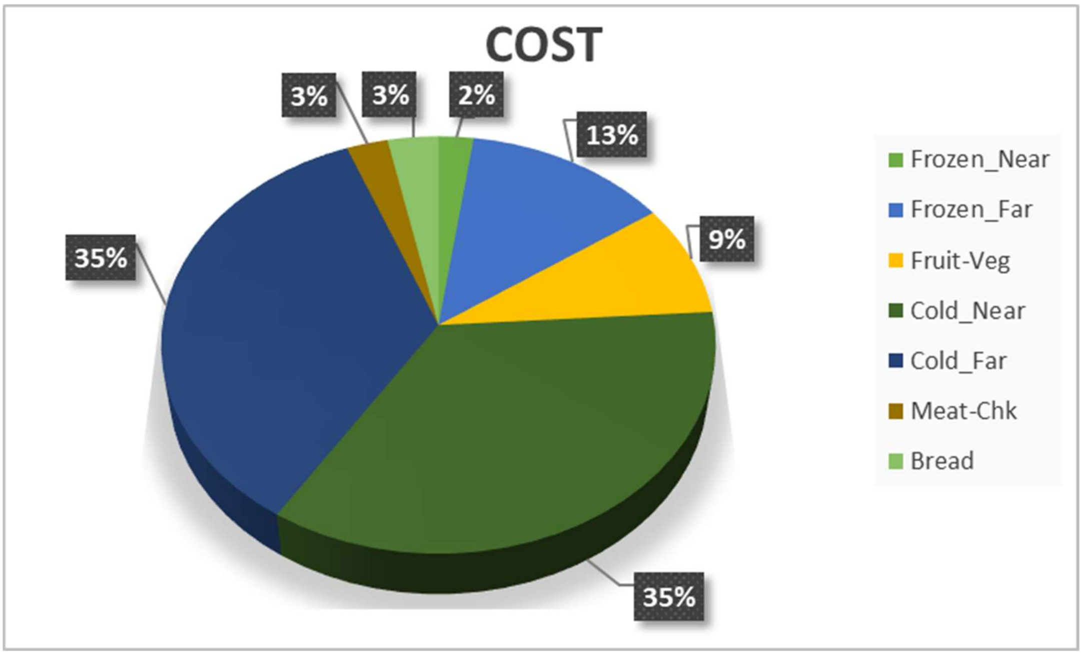

Figure 3.7 : Cost distribution of the routes.

3.1.3 Spatial analysis by using modelbuilder

The analyzes carried out on ArcMap were based on the TSP logic, by considering all stops separately, using the data from a single source and solving the problem. As is done in QGIS, all layers were displayed in the program with the same name and coordinate system and the study started as shown in the Figure 3.8.

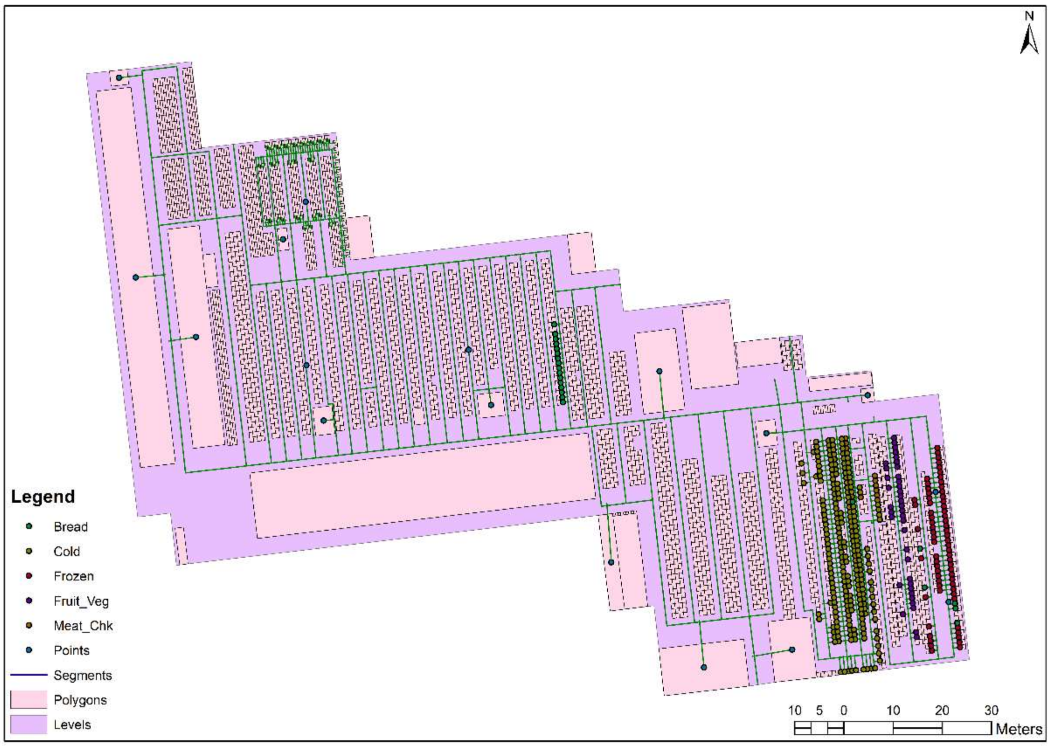

Figure 3.8 : Digitized 2D floor plan on ArcMap.

After the layers were displayed, a geodatabase was created for the project and the operations continued. Creating the "Future Dataset", which is the basic step for Network Analysis under the gaodatabase created here, has been completed by giving it the name "Network". There is no harm in using the default values as they are in the transactions performed here. Subsequently, the "Roads" "Future Class" was created and the operations were completed for the "Network Dataset" where the analysis will be run. Again, the "Network Dataset" has been created with default values and the route layer has been created (Figures 3.9-10).

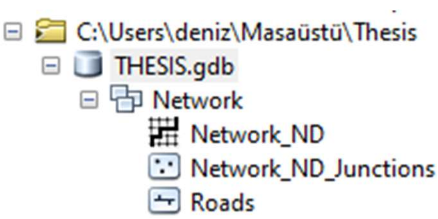

Figure 3.9 : Geodatabase and feature dataset.

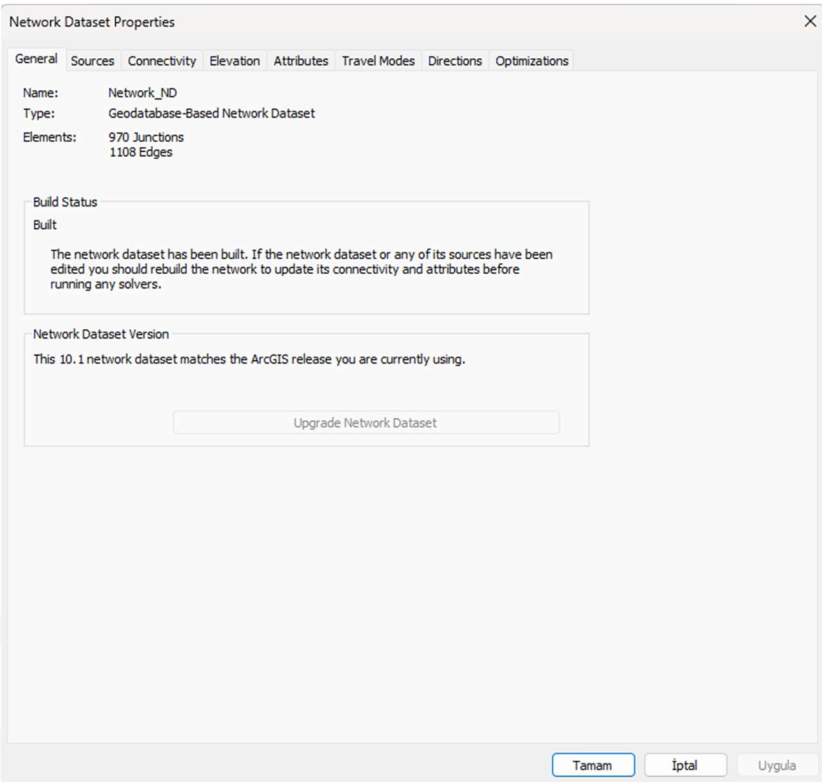

Figure 3.10 : Network dataset properties.

ModelBuilder was used to create the route layer and run the analyses. Route layers were created for each layer and therefore product group, and separate stops were determined for the point layers. After these processes are completed, routes for evacuation can be obtained by visiting the stops for each product group one by one. Just running the scenario defined on ModelBuilder is sufficient. Results are shown in the Figures 3.11-20.

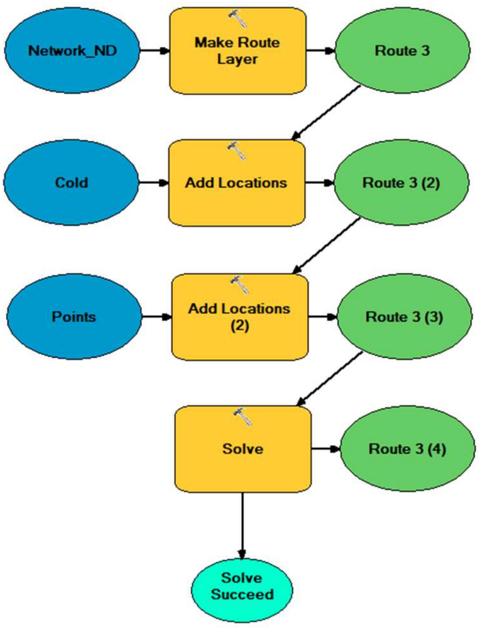

Figure 3.11 : Modelbuilder of cold shelves locations.

Figure 3.12 : Added locations of cold and point.

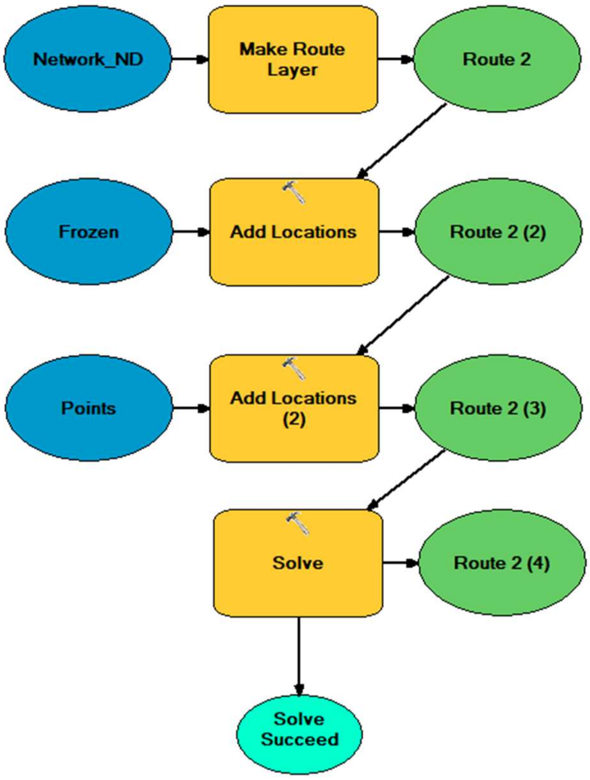

Figure 3.13 : Modelbuilder of frozen shelves locations.

Figure 3.14 : Added locations of frozen and point.

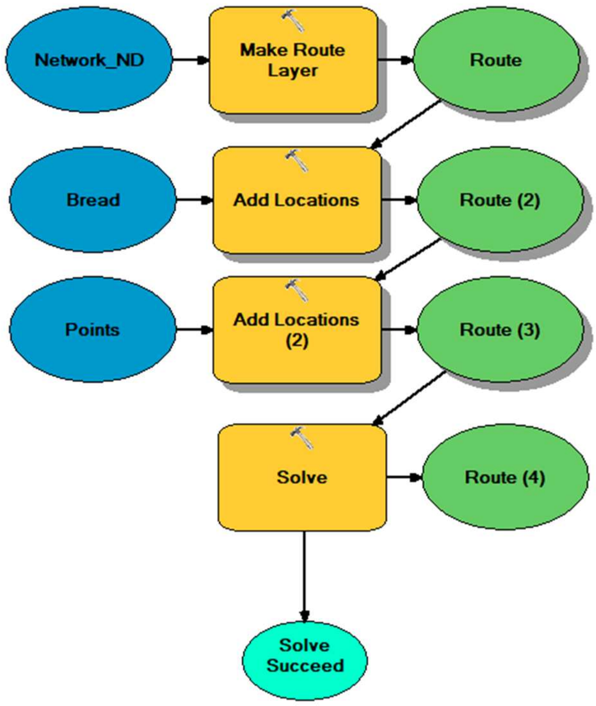

Figure 3.15 : Modelbuilder of bread shelves locations.

Figure 3.16 : Added locations of bread and point.

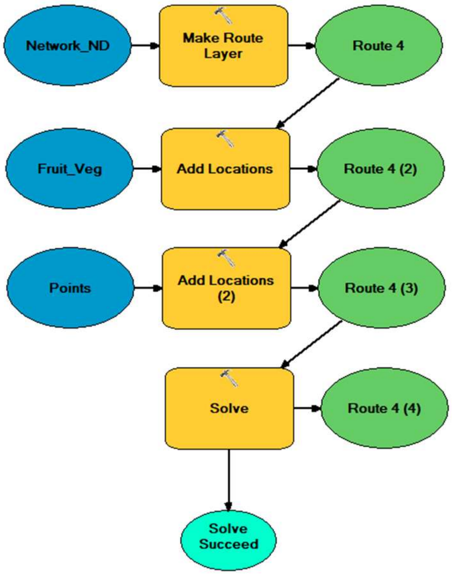

Figure 3.17 : Modelbuilder of fruit-veg shelves locations.

Figure 3.18 : Added locations of fruit-veg and point.

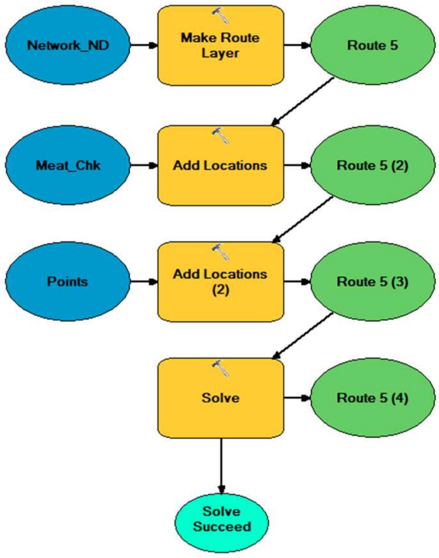

Figure 3.19 : Modelbuilder of meat-chk shelves locations.

Figure 3.20 : Added locations of meat-chk and point.

3.2 Location Based Spatial Analyzes

For explaining the mentioned analysis was desired as follows by applying it with a different data set. The problem in question is addressed by considering the optimal route that a pharmaceutical warehouse official can use to visit certain pharmacies on the European Side of Istanbul. This study was also an evacuation project due to a closure of the related pharmaceutical warehouse. Main difference between two studies is indoor/outdoor positioning system. However, route scenarios are similar and the main problem which is TSP should be solved with Dijkstra's Algorithm. Responsible employees from the evacuation have to visit more than one stop, and this travel has to be the shortest path by regarding alternatives. Hence, the pharmaceutical delivery study was examined in the scope of the supermarket warehouse solution.

Evaluation of the data was completed before starting the analyzes. The data used here was received via OSM and the applications were completed in the TUREF TM30 coordinate system (Figures 3.21-23). The scope of the study is wide and the attribute information used for the relevant analyzes is as follows.

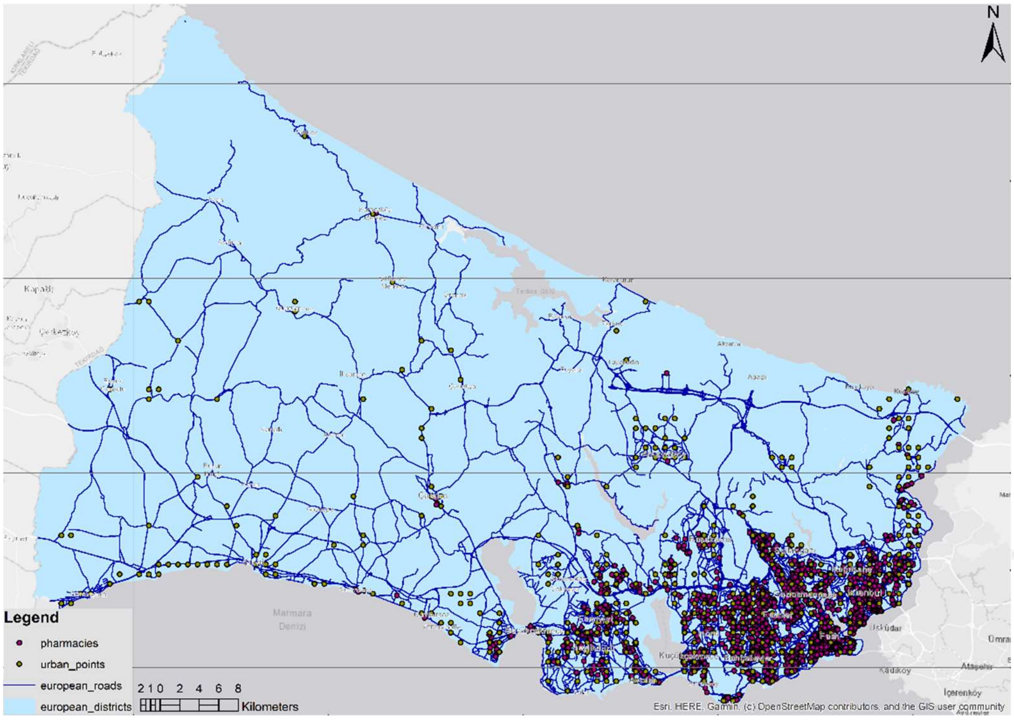

Figure 3.21 : European side pharmacies of the study.

	OBJECTID *	Shape *	ilce_adi	Shape_Length	Shape_Area

Figure 3.22 : Attributes of districts.

	OBJECTID *	Shape *	osm_id	fclass	name	ilce_adi

Figure 3.23 : Attributes of pharmacies.

The district information of each pharmacy is included in these attributes, but its relationship is not established in the raw data. For this reason, it was possible to complete the analyzes on topologically related data by performing “Spatial Join” analysis which is shown with its result in Figure 3.24 and Figure 3.25.

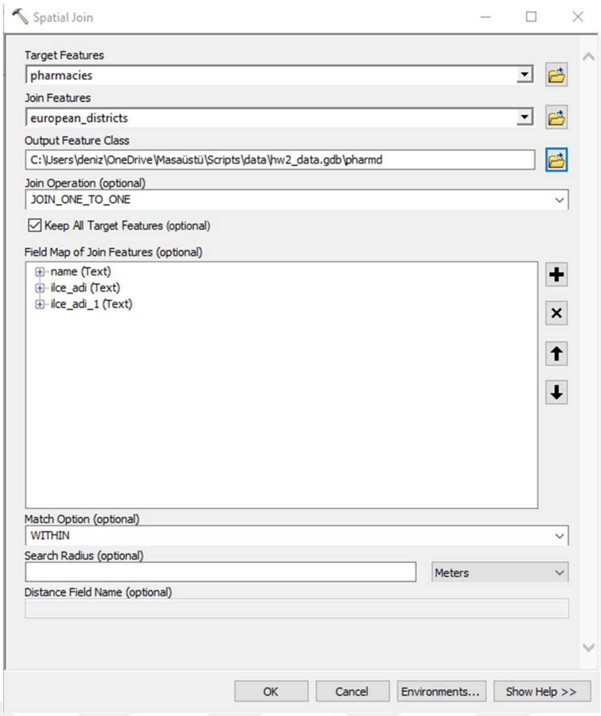

Figure 3.24 : Spatial analysis tool on ArcMap.

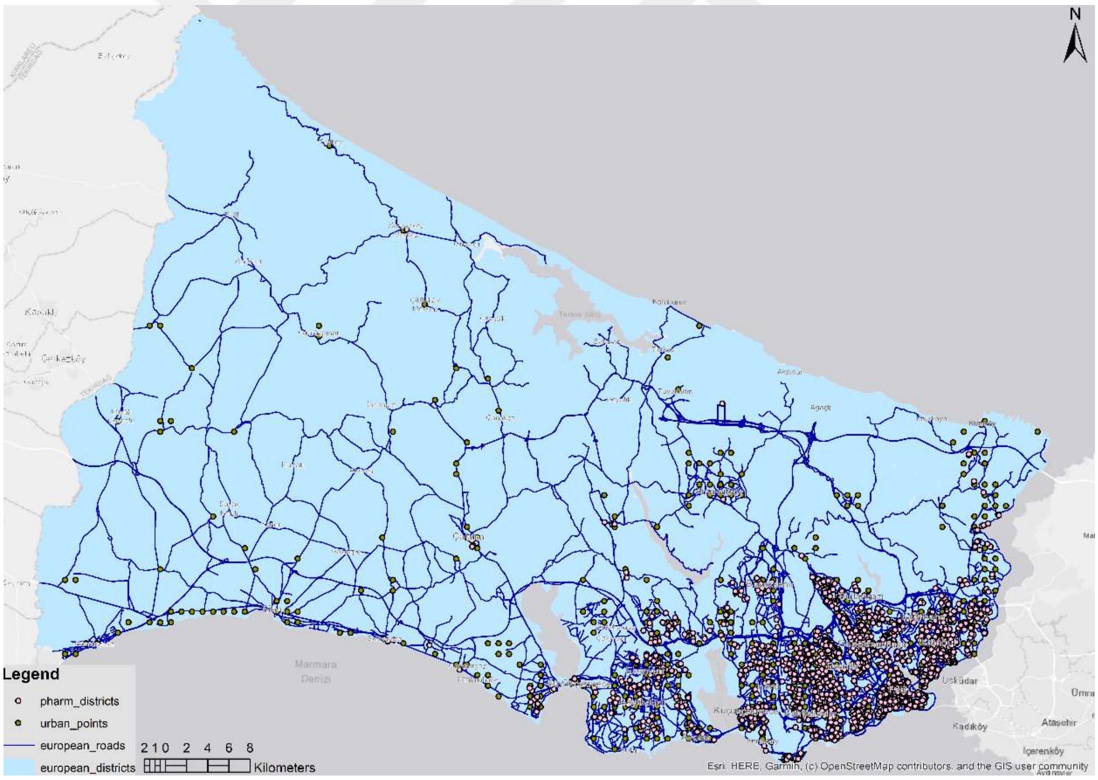

Figure 3.25 : Spatial analysis result of pharmacies and districts.

In the final step before the network analysis, mean centers of the pharmacies were detected according to the districts. To shorten routes and decrease the travel time, this method was chosen for the best practise in the scope of the study. After that, network dataset was created for making route layer (Figures 3.26-27).

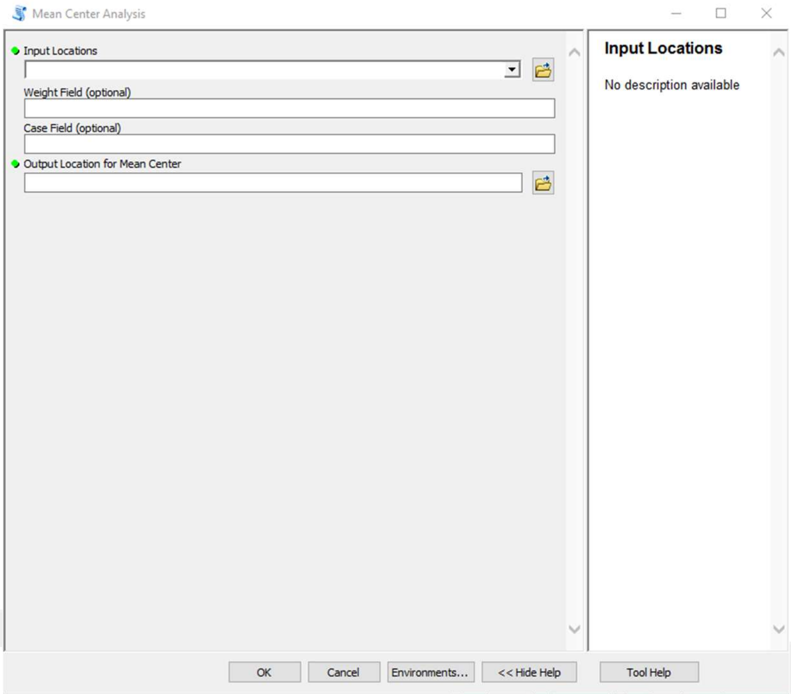

Figure 3.26 : Mean center analysis tool on ArcMap.

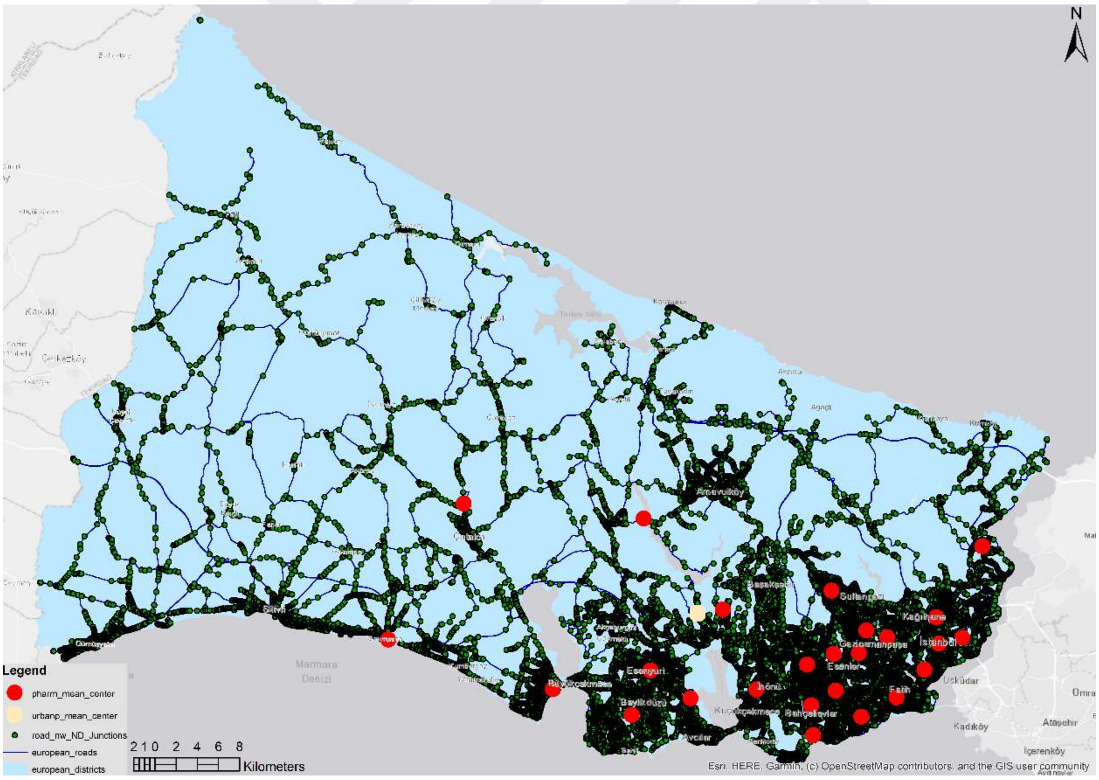

Figure 3.27 : Network dataset of the desired route.

The analysis was solved for a route of 231 kilometers (Figures 3.28-29) and was designed for a total of 27 stops (Figures 3.30). These 27 stops are the points obtained by mean center analysis and their order was created by the program to create a route through the Dijktra’s Algorithm. In the final, the starting point is returned and this is shown in the result output image of the stops. The process steps are the same as those mentioned above for the current warehouse solution problem and are supported by screenshots. The result map is shown at the end and is parallel to the desired result for the project designed to achieve warehouse optimization with interior mapping techniques (Figure 3.31).

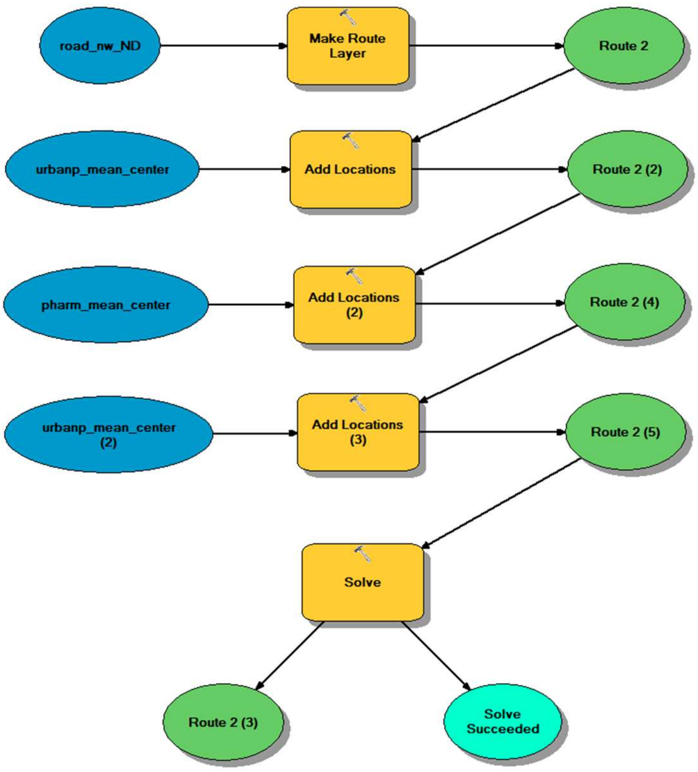

Figure 3.28 : Modelbuilder of the pharmaceutical evacuation route.

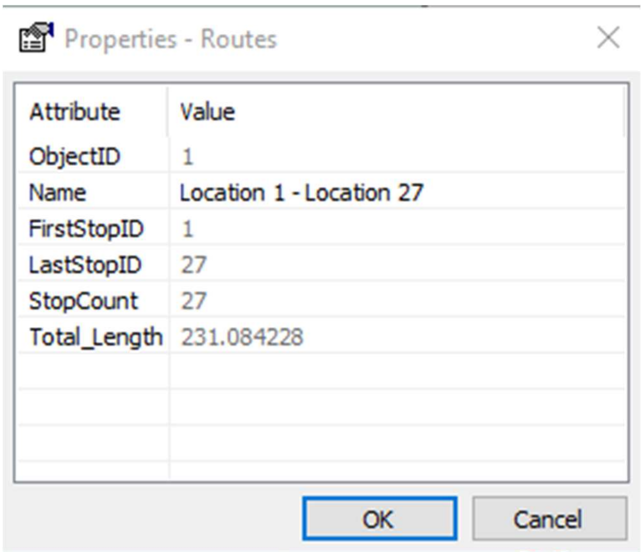

Figure 3.29 : Route information.

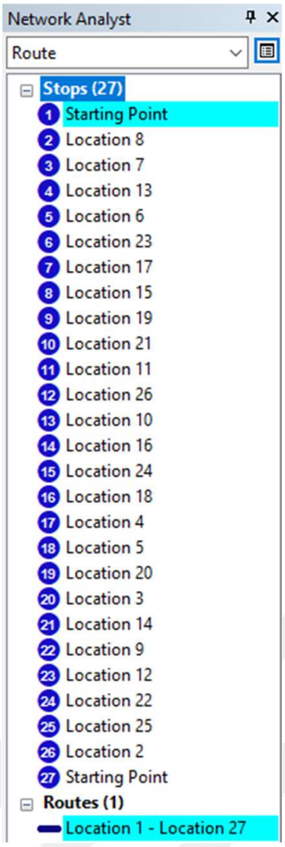

Figure 3.30 : Stops of the route.

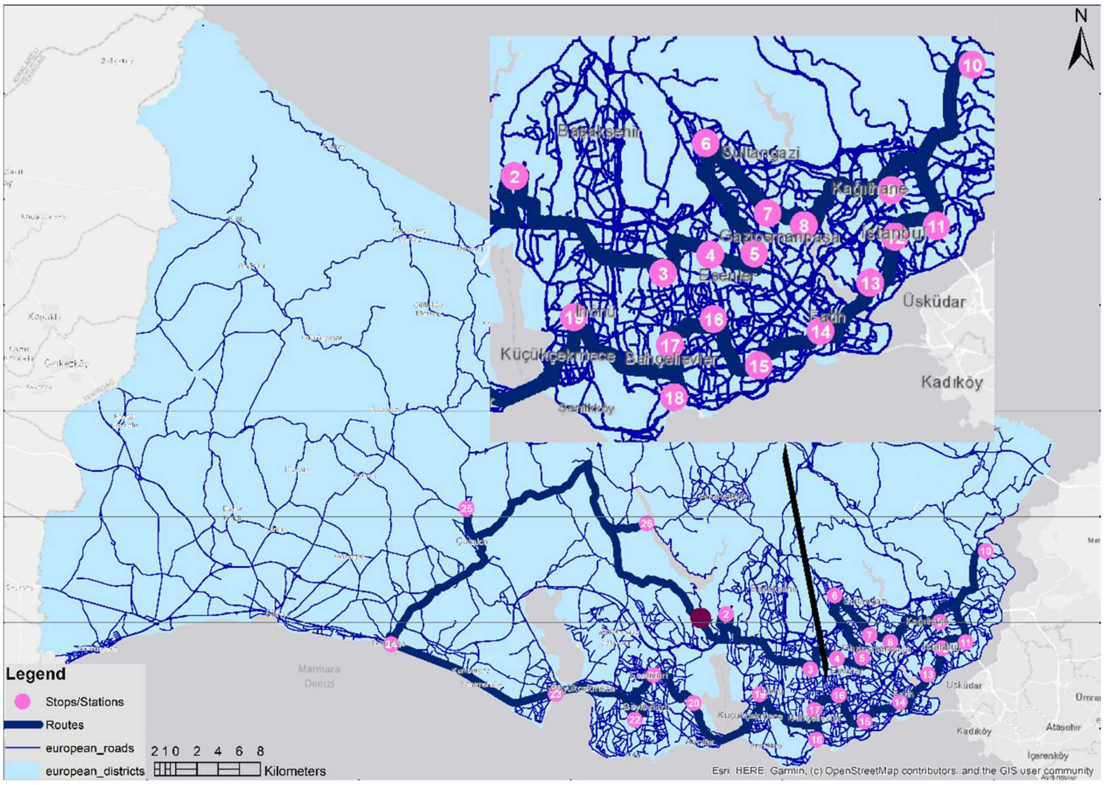

Figure 3.31 : Route of the pharmaceutical evacuation.

3.2.1 Cost calculation of the pharmaceutical warehouse

There is a singular route available for cost analysis in the evacuation of pharmaceutical warehouses. Consequently, the primary factors determining the cost are fuel consumption and the distance of the route. The table displays the whole duration in minutes, revealing that the cost, computed according to unit consumption, amounts to 92,400.00 Turkish Liras. The data shown here are derived from mean values and may not precisely correspond to actual observations. Units and calculation results are shown in the Table 3.2 and Table 3.3.

Table 3.2 : Unit values of the route.

Total Distance	Default Speed	Unloading Time Per Stop	Fuel Consumption Per Km	Fuel Amount Per Km
231 km	50 km/h	5 min.s	10 liter	TRY 40,00

Table 3.3 : Time – cost calculation of the route.

Travel Time (min.s)	Total Fuel Consumption	Total Fuel Amount (TRY)
412,2	2.310,00	92.400,00

4. DISCUSSION

The findings of this study clearly show how important the use of the IoT, one of today's requirements, is in warehouse optimization studies using GIS. Especially in indoor navigation solutions, the inability to use location services such as GPS poses a great difficulty in creating and managing the route. In this context, the integration of advanced technologies such as IoT technologies, IPS and LBS plays a critical role in warehouse management and operational processes. An important finding of the study is the necessity of producing location-based solutions in emergency evacuation scenarios. It is vital to create effective evacuation plans for emergencies that may occur in warehouses and logistics facilities. When the data and cost analysis criteria used when creating the route are evaluated, the strategic importance of obtaining facility management services emerges. This is essential both to ensure rapid and safe evacuation in emergency situations and to increase overall operational efficiency. In the light of technological advances, supporting old systems with new location-based information will be extremely beneficial for businesses in terms of both cost and occupational safety. The use of IoT solutions, IPS and LBS technologies will contribute to more effective and efficient management of warehouse and logistics processes. These technologies offer improvements in many areas in warehouse management, such as automation of processes, inventory tracking and traceability. In addition, optimizing human and fuel consumption in transportation processes stand out as important factors that will increase the effectiveness of evacuation processes. In situations where the capacity of logistics equipment is limited, integrating facility management data with algorithmic analysis reveals a different correlation between time and cost than traditional location-based assessments. This finding highlights the importance of re-evaluating industrial routing technologies that will effectively incorporate facility management data. Traditional approaches cannot fully capture the dynamic interaction between logistics efficiency and cost effectiveness. Therefore, there is an urgent need to conduct research on developing new methods, especially for industrial guidance systems.

Incorporating facility management data into the algorithmic design phase of new approaches will ensure that logistics strategies are not only optimal in terms of efficiency, but also able to adapt to different operating conditions. For example, IoT-based systems provide real-time data flow, allowing rapid intervention in instant situations. These advances have the potential to improve overall operational performance by improving the strength, responsiveness and cost-effectiveness of logistics networks. As a result, this study emphasizes that new methods should be developed in industrial guidance systems and existing systems should be re-evaluated in the light of technological advances. This will allow businesses to make their logistics processes more efficient and cost-effective, while also helping them produce safe and fast solutions in emergency scenarios. Logistics strategies must be flexible enough to adapt not only to current requirements but also to possible future scenarios. This flexibility will contribute to businesses gaining competitive advantage and achieving sustainable growth.

5. CONCLUSION

The discussion highlights the critical need to integrate facility management data into industrial routing systems to increase logistics equipment capacity and optimize both time and cost efficiency. Beyond current research and applications, developing warehouse optimization solutions using indoor navigation requires addressing the complex relationship between logistics and facilities management.

Current "shortest path" solutions face inherent algorithmic limitations and routing challenges, especially in emergency scenarios where adaptability is crucial. As a result, it is imperative to develop more flexible and responsive algorithms that can adapt to such scenarios. In addition, effective use of GIS data is of great importance for solutions where security is at the forefront. To provide comprehensive and reliable results, GIS data must be seamlessly integrated into the planning and operational phases of layout, architecture and logistics.

Integrating facility management data not only increases logistics efficiency but also enables the development of innovative routing strategies that can dynamically respond to changing conditions. This holistic approach to warehouse optimization will result in more durable, safe and efficient logistics systems that meet the demands of contemporary industrial operations. Future research should focus on building these integrated systems, exploring new methodologies for data incorporation, and testing their practical applications in a variety of real-world scenarios.

In addition, this comprehensive strategy will ensure more effective response to emergencies and ensure continuity and rapid adaptation in logistics operations in unforeseen situations. By encouraging collaboration between logistics, facilities management and GIS technologies, significant advances in operational efficiency and safety can be achieved, paving the way for a new era in warehouse optimization. However, the most important point to consider here is that since the data of a repository cannot be obtained as open source, research in this field is generally limited within the sectoral framework. In addition, as an exceptional example, data similar to the dataset used when studying the pharmaceutical store example are not frequently available as open source. Although there are options when looking at the close framework, it is possible to say that the data for studies that can directly reveal Dijktra's Algorithm so clearly are limited.

When warehouse optimization work with location-based services is evaluated, different limitations than indoor navigation solutions stand out. The critical point here is that constraints and hierarchies greatly alter routes, although the data in the current study do not include any. Here it will be possible to talk about limitation and dominance effects such as traffic flow directions, speed restrictions, allowed turns, open/closed roads. The results that can be called the shortest route can become extremely complex due to such parameters, and may cause the algorithm to work incorrectly or not work at all during the creation of the routes. For this reason, it will be beneficial to subject the dataset to be studied to the extent possible to screening and selection processes with database management systems. For example, all kinds of node and edge points that may disrupt the flow and are not necessary, overlapping data, and data whose relationship has not been established but needs to be used during analysis must be identified and manipulated appropriately. The biggest reason why such limitations were not encountered in the pharmaceutical warehouse evacuation example is that the selection criteria were applied while obtaining the data. In addition to all this, transferring deliveries to pharmacies to optimal midpoints can also be applied in order to minimize the effects of these restrictions and hierarchies. However, it would be useful to point out that the effect of external factors on the creation of the route should be associated with the facilities of the facility planned to be evacuated, as in the case of indoor spaces. Factors such as logistics capacity, financial strength, and time constraints are entirely within the capabilities of the warehouse in question.

The conveniences tried to be provided by point-to-point shortest path and ModelBuilder analyzes applied within the scope of thesis research and studies are precisely to produce solutions at the point of existence of these restrictions. In both types of analysis, it is possible to evaluate obstacles, limitations and hierarchy rules within the framework of analysis algorithms and include them in the route. In this framework, which starts with the establishment of topological relationships, topics such as restricted turns, roads with one-way flow, fixed speeds that may vary according to traffic hours, and transit advantages can be evaluated as parameters and analysis results can be created accordingly. The contributions thought to emerge at the end of the study can be matched by determining the limits and observing the need for data support from both private enterprises and public institutions, depending on the time period in which the research is spread. Subsequently, since work has been done on both programs, it will be possible to develop a decision mechanism on which program can be used in different projects to be planned in the future. For example, it has been seen that digitization progresses faster and easier on QGIS, whereas creating diversity in analysis results is easier on ArcMap. Within the scope of the existing data and the project plan, after establishing the relationships of the data, all kinds of parameters were evaluated and preliminary results were obtained for making a selection. Finally, the point that is seen as the most important outcome is that after the evacuation scenario within the warehouse is designed, preparing the post-warehouse route in the same project will provide a great advantage in terms of time. This advantage stands out not for the experts who shape the project, but for the facility management. Because the project, which will be carried out both indoors and outdoors in a single planning, will indicate that the problems in terms of these two scenarios affecting each other can be quickly eliminated. Of course, saving time will also positively improve costs, and of course it will allow planning personnel safety at the maximum level.

In conclusion, addressing the integration of facility management data which can be named as IFC with logistics systems is not just a technical necessity but a strategic imperative. These data contain and presents to managers and end-users 3D data in addition to the whole facility management information. IFC data is utilized in various applications, including creating 2.5D navigation networks, modeling data on IFC schema, simulating hazards, calculating evacuation routes, improving location accuracy in indoor localization research, and visualizing map and location information due to its 3D geometry and semantics [24]. This holistic approach will unlock new potential for innovation, resilience and efficiency in logistics, ultimately transforming warehouse operations to meet the evolving challenges of the industrial environment.

When it comes to all the research and analysis, it has been revealed that indoor navigation and routing in warehouses should be supported by facility management data. This support can also be strengthened with 3D data from the facility management database and the scope of routing can be expanded. This situation will also expand the scope of the weighted cost calculation, which can be made based only on time and fuel consumption with existing data, and will provide an additional basis for future studies in strengthening personnel safety in addition to the cost in such an emergency scenario, with multiple decision analyzes and the scope of routing. At the last point, the architectural model of the interior can be updated with the 3D data that can be used. With the digital twins created here, it will be possible to see what effects the changes planned to be made in the installation of the warehouse or even a layout to be established from scratch will have. Combining the new order with the routing outside the warehouse during the evacuation phase can be completed by revising the door and loading/unloading equipment positions, supporting data such as traffic density, flow direction and speed limits, obtaining the best results and accordingly developing the facility management system.

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APPENDICES

APPENDIX A: Maps

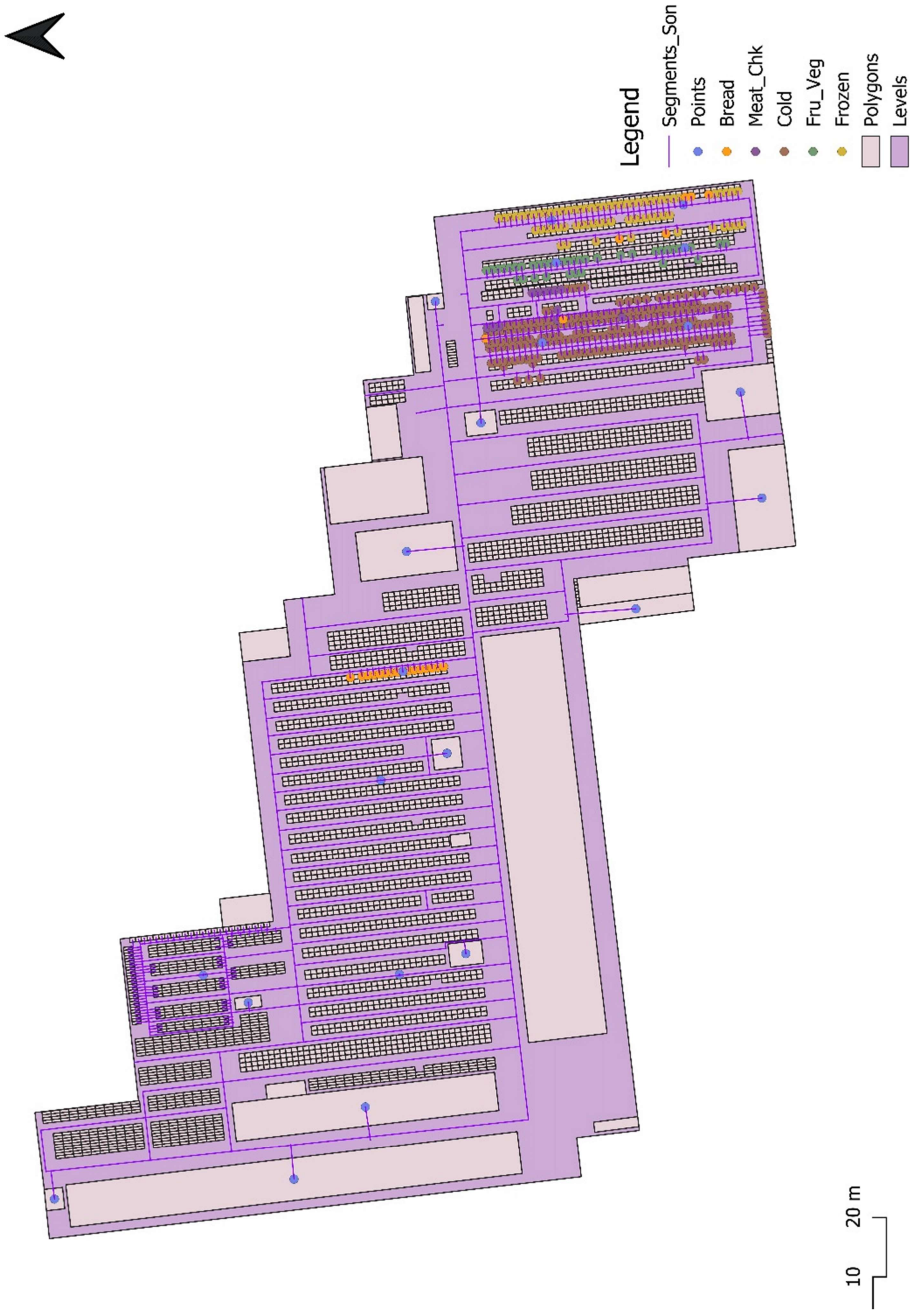

Figure A.3 : Digitized 2D floor plan on QGIS.

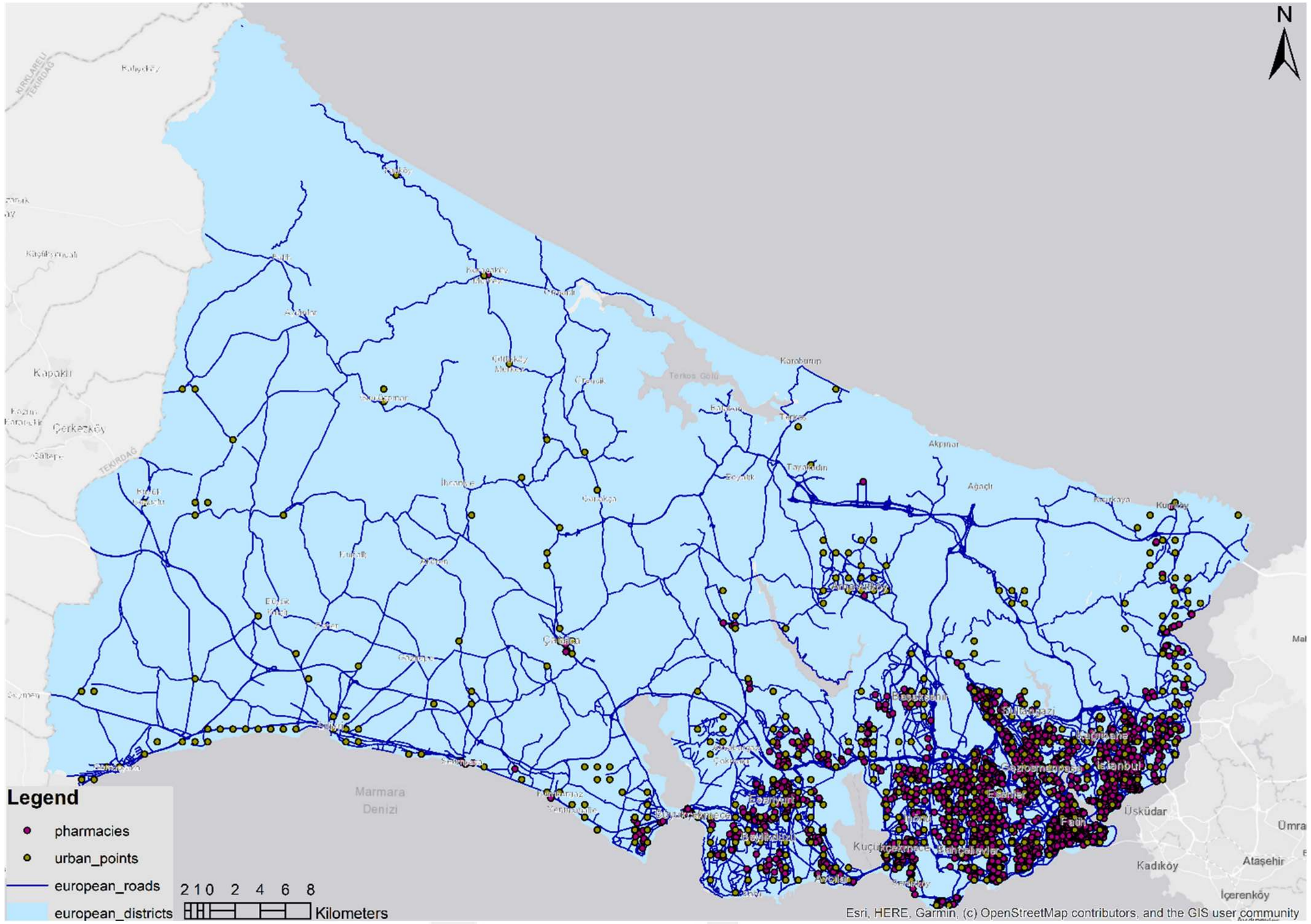

Figure A.2 : Pharmacies and urban points.

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