COST EFFICIENCY ANALYSIS OF ASPHALT PAVEMENT APPLICATIONS IN ROAD CONSTRUCTIONS ACCORDIONING TO DIFFERENT COUNTRIES

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(Doctoral Thesis)

Eskişehir, 2020

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DOCTORAL THESIS

Eskişehir, 2020

T.C.
ESKİŞEHİR OSMANGAZİ ÜNİVERSİTESİ
SOSYAL BİLİMLER ENSTİTİSÜ MÜDÜRLÜĞÜNE

AISHA BASHIR ELFADIL MAKKI tarafından hazırlanan Cost efficiency analysis of asphalt pavement applications in road construction according to different countries başlıklı bu çalışma 03.Temmuz.2020 tarihinde Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Enstitüsü Lisansüstü Eğitim ve Öğretim Yönetmeliğinin ilgili maddesi uyarınca yapılan savunma sınavı sonucunda başarılı bulunarak, jürimiz tarafından İşletme ana bilim Dalında Doktora tezi olarak kabul edilmiştir.

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ONAY
…/ …/ 2020

Prof Dr. Mesut ERŞA
Enstitü Müdürü

03/07/2020

ETİK İLKE VE KURALLARA UYGUNLUK BEYANNAMESİ

Bu tezin/projenin Eskişehir Osmangazi Üniversitesi Bilimsel Araştırma ve Yayın Etiği Yönergesi hükümlerine göre hazırlandığını; bana ait, özgün bir çalışma olduğunu; çalışmanın hazırlık, veri toplama, analiz ve bilgilerin sunumu aşamalarında bilimsel etik ilke ve kurallara uygun davrandığımı; bu çalışma kapsamında elde edilen tüm veri ve bilgiler için kaynak gösterdiğimi ve bu kaynaklara kaynakçada yer verdiğimi; bu çalışmanın Eskişehir Osmangazi Üniversitesi tarafından kullanılan bilimsel intihal tespit programıyla taranmasını kabul ettiğimi ve hiçbir şekilde intihal içermediğini beyan ederim. Yaptığım bu beyana aykırı bir durumun saptanması halinde ortaya çıkacak tüm ahlaki ve hukuki sonuçlara razı olduğumu bildiririm.

AD-SOYAD AISHA BASHIR ELFADIL MAKKI

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GENİŞLETİLMİŞ ÖZET

FARKLI ÜLKELERE YÖNELIK YOL YAPIM ÇALIŞMALINDA ASFALT MALIYET ETKINLIK ANALIZI

BASHIR, Aisha

Doktora- 2020

İşletme Anabilim Dalı

Danışman: Prof. Dr. Nuray Girginer

Problem

Ulaşımın ekonomik değeri ve ülke ekonomileri üzerindeki etkisi hemen her kesim tarafından bilinmektedir. Söz konusu etkinin pozitif katma değeri ancak etkin bir altyapı ile mümkündür. Ulaştırma sistemleri içinde her ne kadar deniz, kara, hava, demiryolu gibi farklı modlar bulunsa da ulaştırma sistemi denildiğinde ilk akla gelen çoğunlukla karayolu ulaşımı ve bağlı olarak (kara) *Yol*'dur. Tarihsel süreç içerisinde şehirler ve komşu ülkeler arasındaki ticaretin geliştirilmesinde araç olarak görülen yollar, günümüzde de ülkelerin gelişmişlik seviyelerinde belirleyici bir unsur olarak önemli rol oynamaktadır. Etkin yol altyapısının oluşturulması ve mevcut yolların iyileştirilmesinde karşılaşılan sorunların giderilmesi, o ülkenin finansal gücüne bağlı olmaktadır. Ülkeler yol altyapılarını iyileştirmek için sınırlı kaynaklarını etkin ve etkili olarak ekonomik büyümelerine pozitif katkı yapacak şekilde yönlendirmek durumundadırlar. Karayolu taşımacılık sektörü özellikle karayolu ağlarıyla doğrudan ekonomik kalkınma ritmine bağlı olarak ulusların refahını etkilemektedir. Literatürdeki çalışmalar, ulaştırma altyapısı ile ekonomik büyüme arasında pozitif bir ilişki olduğunu desteklemektedir (Tripathi ve Gautam, 2010, Peter ve ark., 2015, Mohmand ve ark., 2017 v.b.) Günümüzde birçok ülke sürdürülebilir bir karayolu taşımacılığı altyapısı oluşturmak ve geliştirmek için mücadele etmekte ise de gelişmiş bir karayolu ulaşım altyapısının oluşturulması kolay değildir.

Etkin bir Karayolu Ulaştırma Sistemine sahip olunduğunda, pozitif çarpan etkiler sonucunda piyasalara, istihdama ve ek yatırıma daha iyi erişilebilirlik gibi ekonomik ve sosyal fırsatlar bakımından çeşitli faydalar sağlanmaktadır. Buna karşılık karayolu ulaşımı etkin olmadığında; bağlı olarak yol altyapısı kapasite, güvenilirlik veya kalite bakımından yetersiz olduğunda; ekonomiyi darboğazlara götürebilecek maliyetler ortaya çıkabilmektedir. Bu nedenle ülkeler yol altyapılarının gelişimi ve iyileştirilmesi için yatırımlar yapmakta ve bu yatırımlar için büyük bütçeler ayırmaktadır. Dolayısıyla yol altyapısı ile ilgili çalışmaların ekonomik açıdan değerlendirilerek ülke ekonomisindeki etkisi, yatırımların maliyet olarak etkinliklerinin belirlenmesi, planlanan büyüme hedeflerine erişmede önemlidir.

Karayolu taşımacılığı dendiğinde ilk akla gelen; yol ve asfalttır. Ülkelerin gelişmişlik düzeylerinde asfaltlanmış yollar, etkin altyapıya sahip karayollarına sahip olmak ve bu yolların uzunluğu önemli göstergelerden kabul edilmektedir. Karayolu taşımacılığı açısından yetersiz altyapı ve mevcut altyapıyı iyileştirmede kullanılacak kaynaklardaki kıtlık; bu kaynakların optimum kullanımı konusunda karar alıcıları çeşitli sorunlarla karşı karşıya getirmektedir. Altyapının sözü edilen ekonomik büyümeye etkisi, son zamanlarda altyapı yönetimine olan ilgiyi de arttırmıştır. Günümüzde ülkeler, yol altyapılarını geliştirmeye ve mevcut altyapılarını iyileştirerek sürdürmeye yönelik yatırımlara yönelseler de özellikle etkin olmayan altyapıdan kaynaklanan sorunlarla da karşılaşmaktadırlar. Aktif bir yol altyapısı özellikle karayolu taşımacılığını kullanan işletmelerin ulaşım maliyetlerini azaltmalarına ve bağlı olarak üretim ve toplam maliyetlerini de düşürmeye yardımcı olmaktadır. Bilindiği gibi, bir işletmenin üretim maliyeti ve ulaşım (taşıma) maliyeti arasındaki ilişki dolaylıdır; üretim maliyetlerinin düşmesi, girdilerin maliyet yönlü düşüşü ile doğrudan ilişkilidir. Ulaşım maliyetleri ise üretim süreci sonrasında ortaya çıkmakta ve üretim sonrası süreci kapsamaktadır. Etkin bir alt yapı, işletmelerin küresel pazarlarda rekabet edebilmelerine, bağlı olarak ülke ekonomisinin gelişmesine ve büyümesine de katkı sağlamaktadır. Örneğin, Avrupa Komisyonu 2019 raporuna göre 2016 yılında Avrupa Birliği (AB) ülkelerinin (28 ülke) karayolu ulaşım altyapılarına yaptıkları toplam yatırım yaklaşık 69 milyar €'dur. 2016 yılında AB'de karayolu ulaşım altyapısını geliştirmek için kullanılan bu parasal değer 28 ülkeye bölündüğünde ülke başına söz konusu yatırım 2,43 milyar €'dur. İster gelişmiş ister gelişmekte olsun her ülke, alt yapısını geliştirmede farklı finansal kaynakları kullansa da ekonomik büyümesini engelleyen farklı faktörlerle karşılaşabilir. Bu yüzden, etkin bir alt yapı için sadece finansal kaynağın bulunması değil ayrıca bu kaynağın etkin ve etkili planlanarak tahsisi de önemlidir. Kaynak planlaması ve tahsisi, diğer pek çok alanda olduğu gibi karayolu ulaştırma altyapısı ile ilgili kararlarda da özellikle karar verme sürecinde önemlidir.

Herhangi bir ülkenin yol altyapısının değerlendirilmesi, ülkenin yol ulaşım ile ilgili gelecekteki planlarını yapmasına yardımcı olacak ve gelecekte yol ulaşım sistemine tahsis edilecek bütçeyle ilgili kararlara katkı sağlayacaktır. Diğer yandan, etkin yol altyapısı, kamu ve özel sektörde faaliyette bulunan işletmeleri, karayolu ulaşımı kullanarak mal ve hizmetlerini bir yerden başka yere taşımadaki yaşanan sorunlara çözüm getirerek mikro düzeyde de işletmelerin yol ulaşım yönlü uygulama ve politikalarını etkileyecektir. Etkin bir yol altyapısının sağlanması, kaza oranının azaltılmasına da katkıda bulunarak ülke içindeki trafik kazalarını ve olumsuz sonuçlarını (ölüm oranı, maddi hasar) azaltacaktır. Ayrıca, insanlara kısa sürede bir yerden diğer yere hareket etmelerinde de kolaylık sağlayarak iç ve dış turizme de katkılar sağlayacaktır.

Yol yapımlarının en önemli bileşenlerinden, başka bir ifadeyle yol yapımlarının önemli hammaddelerinden birisi asfalttır. Yol yapım çalışmalarının temelde bir hizmet olduğu düşünüldüğünde; bu hizmetin sağlanması için etkin ve etkili bir alt yapının kurulması zorunludur ki asfalt, bu süreçte sistemin önemli bir bileşeni olarak kullanılmaktadır. Her türlü yol inşaatı ve bakımını yapmak için kullanılan agrega, bağlayıcı ve dolgu maddesinin bir karışımıdır. Asfalt serimi, sıralı ve özel adımlardan oluşan bir süreçtir. Sürecin her aşamasında farklı kaynaklar kullanılmaktadır. Kullanılacak kaynakların sınırlı olduğu dikkate alındığında asfalt uygulamalarının da planlanması gerektiği açıktır. Söz konusu planlamada kıt olan (örneğin petrol türevi bitüm ve çevresel açıdan agregalar) kaynaklar nedeniyle asfalt üretiminde farklı alaşımların geri dönüşüm (cam atık, inşaat atıkları gibi) yoluyla kullanımları da gündeme gelmektedir. Dolayısıyla asfalt malzemelerin kullanılması, üretim ve serimi karar vericiler açısından zor, ancak çözülmesi gereken önemli sorunlardan olup, yapısında çok sayıda nicel ve nitel kriterler barındırması nedeniyle de çok kriterli bir karar problemi niteliğindedir. Örneğin, bir yol inşasında karar vericiler açısından; kaplanacak yolun uzunluğu, asfalt kaplamaya nerden başlanacağı, nerede sonlandırılması gerektiği, asfalt kaplamada ne tür bir karışımın kullanılacağı gibi pek çok sorunun yanıtlanması karar vericilerin asfalt kaplama planlarını etkili bir şekilde belirlemelerine yardımcı olacaktır.

Dünyadaki hiçbir ürüne benzemeyen Asfaltı ve her türlü karışımını üretmek; çaba, iş gücü, malzeme ve ekipman gerektirse de asfalt üretimi için gerekli kaynakların maliyeti, ülkelerin ekonomik durumuna göre değişmektedir. Bazı ülkeler bu kaynakları yerel olarak elde edebilme şansına sahipken diğer bazı ülkeler ne yerel olarak temin edebilme ne de dış kaynaklardan temin etmede yeterli bütçeleri vardır. Bu nedenle, kaynakların etkin kullanımı her alanda olduğu gibi yol yapım ve asfalt için de önemlidir.

Karayolu taşımacılığının sözü edilen etkileri nedeniyle bu alanda etkinliğin sağlanabilmesi için yol altyapısının temel bileşenlerinin ayrıntılı olarak incelenmesi ve bu bileşenlerin ülke ekonomisi üzerindeki etkinlik derecelerinin belirlenmesi gereklidir. Özellikle ülkeler arasındaki makro düzeyde şiddetlenen rekabet açısından ülke grupları içindeki bu bileşenlerin düzeylerinin ve etkilerinin ortaya konulması, bu yönde politikaların oluşturulmasına yardımcı olacaktır. Ayrıca, bir ülkenin maliyet açısından etkin bir yol altyapısı geliştirmesi, karayolu ulaşım sistemine olumlu bir değişiklik olarak yansıyacaktır. Yol altyapısındaki etkinlik, ülkenin ekonomisine de bağlı olarak olumlu katkılar sağlamasının yanı sıra yol altyapısı ile ilgili mevcut durumu anlatan bir model sunmak, kısa ve uzun vadede bu konuda iyileştirme yapmaya imkân verebilecektir.

Literatürde farklı alanlarda ülkelerin gruplandırılmasına yönelik daha çok kümeleme analizinin uygulandığı çok sayıda çalışma bulunmaktadır. Söz konusu çalışmalarda ülkelerin gruplandırılmasında Kümeleme Analizi (Kuşkaya ve Gençoğlu, 2017; Gençoğlu ve Kuşkaya, 2016; Michinaka ve ark, 2011; Tsangarides ve Qureshi, 2008; Diaz- Banilla ve ark, 2000), ÇBÖA (Dickes vd, 2011) ya da her iki teknik (KA ve ÇBÖA) (Yenilmez ve Girginer, 2016; Girginer, 2013; Akkucuk, asfalt karışım etkinliğini inceleyen tek bir çalışma bulunmaktadır (Li ve ark, 2013). Bu alanda yapılan diğer çalışmaların çoğunluğunda karayolu bakım etkinliği incelenmiştir (Fallah- Fini ve ark, 2015; Ozdek ve ark, 2010; Rouse ve Chiu, 2009; Kazakov ve ark, 1989). Ayrıca, genel olarak karayolu ulaşımını inceleyen ve aynı zamanda veri zarflama analizi (VZA) kullanan az sayıda çalışma da bulunmaktadır (Sarmento ve ark, 2017; Fu, 2013). Söz konusu çalışmalar, asfalt ve karayolu etkinliğine yönelik olup asfalt ve asfalt uygulamalarının maliyet etkinlik analizine bir çalışma bulunmamaktadır. Benzer şekilde Gri İlişki Analizi de literatürde daha çok etkin ve uygun maliyetli ülkeler sıralamasında kullanılmışsa da karayolu ulaşım alt yapısıyla ilgili alanda asfaltın farklı özelliklerini incelenmesinde GİA kullanılmıştır (Yu ve ark, 2017; Cheng ve ark, 2016, Sun ve ark, 2014 vb.).

Literatür incelemesinden görüldüğü gibi özellikle asfalt uygulamaları açısından farklı ülkelerin gruplandırılması ve performanslarının belirlenerek maliyetlerle ilişkilendirilmesinin yanı sıra bu uygulamalar açısından performans üzerindeki önemli değişkenlerin ve etkin olan ülkelerin sıralanması şeklinde bütünleşik bir çalışma bulunmamaktadır. Literatürdeki bu eksikliği gidererek katkı sağlama kapsamında b*u çalışmanın temel problemi;*

Türkiye ve AB ülkelerinin yol yapım çalışmalarında asfalt etkinliğini ve asfalt maliyet etkinliğini analiz ederek etkin olmayan ülkeler için performanslarını iyileştirmelerine yönelik önerilerin yanı sıra etkin olan ülkeleri kendi içlerinde etkinlik ve maliyetteki etkinlikleri açısından sıralamaktır.

Bu bağlamda çalışmanın aynı alanda yapılacak olan diğer araştırmalara özellikle ulaştırma sisteminin diğer modlarının (Havayolu, Raylı sistemler, Deniz yolu vb) altyapıları için de farklı ülkeler açısından örnek olması beklenmektedir.

Amaç

Yukarıdaki açıklamalardan hareketle bu çalışmanın temel amacı; Türkiye ve seçilmiş bazı ülkelerin asfalt uygulamalarını performans açısından değerlendirmektir. Bu çalışmada Türkiye ve seçilen bazı ülkelerin asfalt uygulamalarının performansları etkinlik ve maliyet etkinlik analizi kullanarak incelenmektedir. Bu temel amaç doğrultusunda çalışmanın alt amaçları şunlardır:

1- Bazı ekonomik göstergeler bakımından Türkiye'nin benzer olduğu ülke grubunu belirlemek

2- Türkiye'nin yer aldığı ülke grubun farklı senaryolarla asfalt uygulamalarındaki etkinliklerini analiz etmek

3- Çalışmanın üçüncü alt amacı da etkin ve uygun maliyetli ülkelerin ve değişkenlerin etkinlik bakımından sıralarını belirlemektir.

Asfalt performansını ölçmek için etkinlik ve maliyet etkinlik analizlerinin kullanılmasının gerekçeleri şu şekilde açıklanabilir:

- Asfalt üretimi, farklı kaynaklardan girdi materyallerinin toplanması gereken bir süreçtir ve bu kaynakların her birinin kendine ait bir üretim süreci bulunmaktadır. Bu nedenle asfalt performansını ölçmenin faydaları bulunmaktadır.

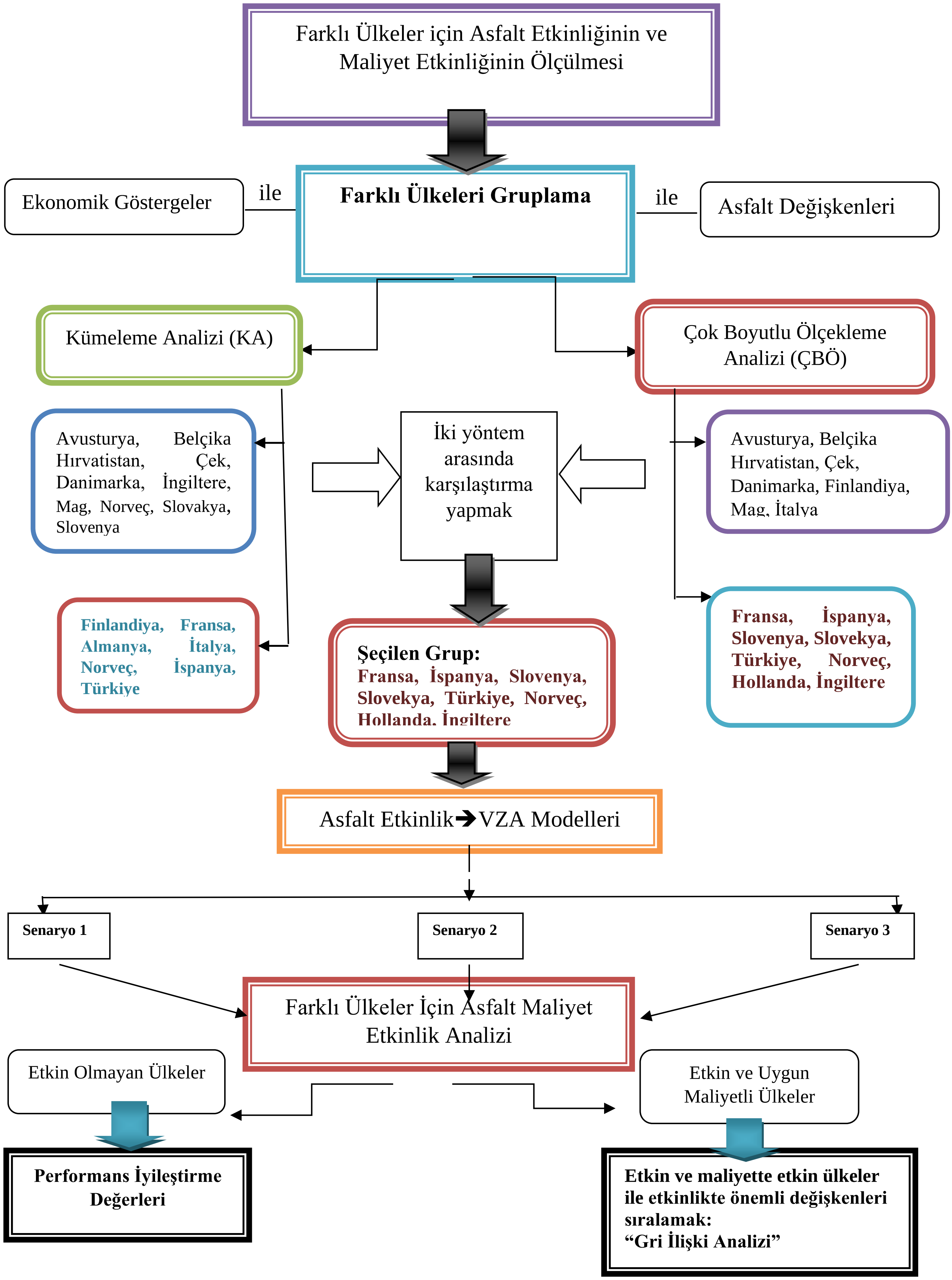
- Avrupa ülkelerinin çoğunun ekonomik olarak gelişmiş ülkeler olduğu düşünüldüğünde, bu ülkelerdeki asfalt performansının ölçülmesi ile asfalt kaplama uygulamaları bakımından etkin olup olmadıkları; başka bir ifadeyle daha az malzeme israfı, çaba ve bütçe ile asfalt uygulamalarındaki başarılarına yönelik bulgular ortaya çıkmaktadır. Asfalt uygulamaları bakımından performansı düşük ülkeler, etkin olan ülkeleri referans alarak onları asfalt uygulamalarındaki başarıları nedeniyle rol model olarak alıp performanslarını onlara benzemeye çalışarak iyileştirebileceklerdir.

- İşlerin doğru şekilde gerektiği gibi yapılması olarak tanımlanabilen Etkinlik, üretim sürecinde kullanılan girdilerle çıktıların karşılaştırılmasını sağlayarak herhangi bir birimin malzeme, emek ve para israfını önleme yeteneğini geliştirmesine yardımcı olur. Etkinlik bu çalışma kapsamında asfalt uygulamaları açısından düşünüldüğünde; asfalt uygulamalarındaki girdileri doğru şekilde kullanarak olması gerektiği gibi asfalt uygulamalarını gerçekleştirmeyi başaran herhangi bir ülke asfalt uygulamalarında etkin kabul edilmektedir.

Yöntem

Çalışmanın amaçları doğrultusunda uygulanan analizler bütünsel bir yaklaşımla Çizelge1 de bir akış şeması olarak verilmiştir.

Çizge 1: Analiz Akış Şeması



1- *Kümeleme Analizi ve Çok Boyutlu Ölçekleme Analizi İle Ülkelerin Gruplandırılması:*

Ülkeler bağlamında asfalt performansının ölçülebilmesi için ülkeleri karayolu alt yapısı ve ekonomi olarak benzer gruplar içinde karşılaştırmak gerekir. Çalışmanın bu amacına ulaşabilmek için farklı değişken kombinasyonları için asfaltla ilgili değişkenlerin yanında bazı ekonomik değişkenler de kullanılmıştır.

Kullanılan asfalt değişkenleri şunlardır: Asfalt endüstrisindeki şirket sayısı (üretim ve döşeme) (X1), Toplam bitüm tüketimi (milyon ton) (X2), Toplam asfalt üretimi (milyon ton) (y1), Toplam otoyol uzunluğu ve ana yol (km) (y2). Ekonomik göstergeler bunlardır; nüfus yoğunluğu (km kare başına düşen kişi) (NY), Yüzey alanı (km kare) (YA), Toplam nüfus sayısı (TN), Kişi başına düşen GSYİH (ABD doları), Kişi başına GSMG.

Türkiye ve 16 AB ülkesinin gruplamasında iki yöntem kullanılmıştır. Kümeleme Analizi (KA) ve Çok Boyutlu Ölçekleme Analizidir (ÇBÖA). Kümeleme Analizi, nesneleri çok çeşitli farklı özellikleri bakımından birbirlerine benzer olanları homojen olacak şekilde kümelerde sınıflandırmaya izin veren istatistiksel bir yöntemdir. Çok Boyutlu Ölçekleme Analizi de kümeler veya gruplar arasında benzerlik gösteren niceliksel değerlendirmeler sağlayan, veri toplamadaki karmaşıklığı azaltmaya yardımcı olan bir yöntemdir. Çalışmada her iki gruplama yöntemi de kullanılarak, literatür ve uzman görüşlerinden hareketle Türkiye'nin de yer aldığı asfalt uygulamaları açısından en benzer olan ülke grubu seçilmiştir ve sonraki analizler (Veri zarflama analizi, Gri İlişki Analizi) bu ülke grubuna yönelik yapılmıştır. Her iki teknikte de gruplandırmada ortak değişkenler alınmıştır. Çalışmada belirlenen değişkenler itibariyle 17 ülkenin (Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Fransa, Almanya, İngiltere, Macaristan, İtalya, Hollanda, Norveç, Slovakya, Slovenya, İspanya ve Türkiye) aynı yıl için verilerine ulaşıldığından gruplandırma bu ülkeler için yapılmıştır. Sonuçlara göre her iki analizinden önerilen dokuz kombinasyonla iki küme oluşturulmuştur. İki teknikteki gruplamalar 4, 6, 7 ve 8. değişken kombinasyonlarında aynı kümeler elde edilmiştir. Buna karşılık değişken kombinasyonları (2, 3 ve 9) farklı gruplandırma sonuçları vermiştir. Tablo1'de söz konusu ülke grupları her iki tekniğe göre değişken kombinasyonlarına göre verilmiştir. Gruplandırmada ÇBÖA ile elde edilen grupların gerçek hayattaki ve uygulamadaki benzerliğe KA'ndan daha uygun olduğu görülmüştür.

Tablo 1: Farklı Değişkenlere Göre KA ve ÇBÖA

Değişkenler	Kümeleme Analizi		ÇBÖ Analizi	
	1	2	1	2
X1, X2, Y1, Y2	Çek Cumhuriyeti	Diğer 16 ülke	İspanya, Slovakya, Slovenya, Türkiye, Norveç, Hollanda	Avusturya, Belçika, Hırvatistan, Çek, Finlandiya, Fransa, İngiltere, Macaristan, İtalya
X1, X2, Y1, Y2, YA	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Büyük Britanya, Macaristan, Hollanda, Slovakya, Slovenya	Finlandiya, Fransa, Almanya, İtalya, Norveç, İspanya, Türkiye	Fransa, İspanya, Slovakya, Slovenya, Türkiye, Norveç, Hollanda, İngiltere	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Macaristan, İtalya
X1, X2, Y1, Y2, TN	Avusturya, Belçika, Hırvatistan, Çek Danimarka, Finlandiya, Macaristan, Hollanda, Norveç, Slovakya, Slovenya	Fransa, Almanya, İngiltere, İtalya, İspanya, Türkiye	Hollanda, Norveç, Slovakya, Slovenya, İspanya, Türkiye.	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Fransa, İngiltere, Macaristan, İtalya
X1, X2, Y1, Y2, GSYİH	Macaristan hariç tüm ülkeler	Macaristan	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Fransa, Macaristan, Hollanda, İngiltere, İtalya	Norveç, Slovakya, Slovenya, İspanya, Türkiye
X1, X2, Y1, Y2, GSMG	Çek Cumhuriyeti hariç tüm ülkeler	Çek Cumhuriyeti	Norveç, Slovakya, Slovenya, İspanya, Türkiye	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Macaristan, Danimarka, Finlandiya, İtalya, Fransa, İngiltere
X1, X2, Y1, Y2, GSYİH, GSMG	Macaristan hariç tüm ülkeler	Macaristan	Avusturya, Belçika, Hırvatistan, Çek Danimarka, Finlandiya, Fransa, Macaristan, İngiltere, İtalya	Hollanda, Norveç, Slovakya, Slovenya, İspanya, Türkiye
X1, X2, Y1, Y2, GSYİH, GSMG, NY	Macaristan hariç tüm ülkeler	Macaristan	Avusturya, Belçika, Hırvatistan, Çek, Danimarka, Fransa, İngiltere, Macaristan	Finlandiya, İtalya, Hollanda, Norveç, Slovakya, Slovenya, İspanya, Türkiye
X1, X2, Y1, Y2, GSYİH, GSMG, NY, YA	Macaristan	Macaristan hariç tüm ülkeler	Fransa, İngiltere, Hollanda, Norveç, Slovakya, Slovenya, İspanya, Türkiye	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Almanya, İtalya, Macaristan
X1, X2, Y1, Y2, GSYİH, GSMG, NY, YA, TN	Fransa, Almanya, İngiltere, İspanya, Türkiye	Avusturya, Belçika, Hırvatistan, Çek Danimarka, Finlandiya, Macaristan, Hollanda, Norveç, Slovakya, Slovenya	Fransa, Almanya, İngiltere, İtalya, Norveç, İspanya, Türkiye	Avusturya, Belçika, Hırvatistan, Çek Cumhuriyeti, Danimarka, Finlandiya, Hollanda, Slovakya, Slovenya

2- Veri Zarflama Analizi İle Ülkelerin Asfalt Uygulama Etkinliklerinin Belirlenmesi ve Maliyet Etkinlik Oranlarının Elde Edilmesi:

Veri Zarflama Analizi (VZA), genellikle farklı katkıları çeşitli getirilere dönüştüren Karar Verme Birimleri (KVB'leri) olarak adlandırılan bir dizi yapının performansını değerlendirmede yaklaşımdır. Çalışmada bir önceki aşamada elde edilen ülke grubunun asfalt uygulama performansını belirlemek amacına ulaşmak için VZA kullanılmıştır. Benzer yapı sergileyen bu ülkeler, asfalt uygulamalarında da yine benzer girdilerle aynı çıktıyı üreten çalışmanın VZA modellerindeki karar verme birimleridir. Bu aşamada farklı girdi ve çıktı değişkenlerinden oluşan senaryolarla ülkelerin asfalt uygulama performansları etkinlik boyutunda belirlenmiştir. Çalışmanın ikinci alt amacı olan ekinlik analizini gerçekleştirebilmek için üç senaryo üzerinde iki girdi ve iki çıktı asfalt değişkenlerine ait veriler kullanılmıştır.

Girdi değişkenleri: Asfalt endüstrisindeki şirket sayısı (X1) (üretim ve döşeme), Toplam bitüm tüketimi (X2) (milyon ton)

Çıktı değişkenleri; Toplam asfalt üretimi (Y1) (milyon ton), Toplam otoyol uzunluğu ve ana yol (Y2) (km).

Senaryolar: Senaryo1: (X1, X2, Y1 ve Y2), Senaryo 2 (X1, X2 ve Y1), Senaryo 3 (X1, X2 ve Y2) değişken kombinasyonlarından oluşmaktadır. Senaryolardaki girdi, çıktı değişkenleri, sembolleri ve veri kaynakları Tablo 2'de gösterilmiştir.

Tablo 2: Asfalt Ekinlik ve Maliyet Etkinlik Analizinde Kullanılan Değişkenler

Değişkenler	Semboller	Veritabanı
Maliyet değişkenleri: • Karayolu altyapı yatırım harcamaları (milyon €) • Karayolu altyapı bakım harcamaları (milyon €) Girdi Değişkenleri: • Asfalt endüstrisindeki şirket sayısı (üretim ve döşeme) • Toplam bitüm tüketimi (milyon ton)	**KAYH** **KABH** **X1** **X2**	OECD.stat database OECD.stat EAPA EAPA
Çıktı Değişkenleri: • Toplam asfalt üretimi (milyon ton) • Toplam otoyol uzunluğu ve ana yol (km)	**Y1** **Y2**	EAPA Eurostat ve Statista veritabanı

Etkinlik analizinde çıktı odaklı Veri Zarflama Analizinin (VZA) iki yöntemi (CCR ve BCC) kullanılmış ve etkin olmayan ülkeler için performans iyileştirme değerleri hesaplanmıştır. Etkinlik analizinde (BCC) modeli sonuçlarının, (CCR) modeli sonuçlarından daha geçerli olduğu söylenebilir. Türkiye, İspanya ve Fransa senaryo 1 ve 2'de (CCR) modeli için etkin değildir. Diğer taraftan, Slovakya ve İngiltere üç senaryoda ve (CCR ve BCC) modellerinde etkin olan ülkeler olarak ortaya çıkmıştır. Her model için etkin olmayan ülkeler için potansiyel iyileştirme değerleri elde edilmiştir. Örneğin senaryo (1) için (BCC) modelinin sonuçlarına göre; Norveç'in toplam asfalt üretimi çıktılarını ve toplam otoyol ve ana yol uzunluğunu (çıktılarını) aynı oranda 13,40 oranında artırması, Senaryo 2 için aynı modelin sonuçlarına göre Norveç'in toplam asfalt üretimini %16,53 arttırması durumunda etkin bir ülke olabilecektir. Bu durumda, Norveç'te asfalt performansının eksikliğinin nedenini bilmek için daha fazla araştırma yapılması gerektiği önerilmiştir.

VZA ile ülkelerin asfalt uygulamadaki etkinliklerinin belirlenmesinden sonra Maliyet etkinlik analizi için maliyet etkinlik oranları hesaplanmıştır. Maliyet etkinlik analizinin gerçekleştirmesinde Karayolu altyapı yatırım harcamaları (milyon €) ve Karayolu altyapı bakım harcamaları (milyon €) değişkenlerinin verileri kullanılmıştır. Sonuçlara göre; maliyet etkinlik oranlarının hesaplanmasında kullanılan (CCR ve BCC) modelinin etkinlik sonuçlarına göre, Slovenya üç senaryoda maliyette en az artış sağlayarak en üst sırada yer almıştır. Ayrıca, Senaryo 1 ve 2'de, (CCR) modeli sonuçlarına göre Türkiye ve (BCC) modeli sonuçlarına göre Fransa, maliyetin en yüksek artışlarına sahiptir ki bu da Türkiye'nin (CCR) modeli değerleriyle maliyet etkinlik analizinde en altta yer almasına neden olmuştur. Fransa (BCC) modeline göre maliyet etkinlikte en alt sırada yer alırken Senaryo 3'e göre, her iki model için de (CCR ve BCC) Fransa en yüksek maliyet artışına sahip ülke olarak belirlenmiştir.

3- *Gri İlişki Analizi ile Ülkeleri ve Değişkenleri Asfalt performansları bakımından sıralanması:*

Çalışmanın son alt amacını gerçekleştirebilmek için Gri İlişki Analizi kullanılmıştır. Gri ilişkisel analizin (GİA) temel düşüncesi, veri serisine dayanan ilgili faktörler arasındaki ilişkiyi tanımlamak için kullanılabilecek gri bir oran düzeni bulmaktır. GİA aşamaları, veri seti hazırlama ve matrisini oluşturma ile başlar, gri ilişkisel oranları hesaplama ile bitir. Bu çalışmada GİA kullanma sebebi şu ki; VZA etkin ve uygun maliyetli ülkeler sıralamaları veremediği için bu durumda GİA kullanmayı tercih etmiştik. Bu analizin yardımıyla, etkin ve uygun maliyetli ülkeler ve değişkenler için etkinlikte önem dereceleri belirlenmiştir. Ülkeler için etkinlik sıralamasının sonuçları; senaryo 1'e göre, İngiltere ve Slovakya birinci ve ikinci olarak; senaryo 2 ve 3'e göre, Slovakya ve Slovenya birinci ve ikinci sıradadır. Ayrıca, ülkeler için etkinlik sıralamasının sonuçları; Senaryo 1 ve 2'ye göre Türkiye, en düşük sıralamaya sahip olan yedinci sırada yer almıştır. Diğer yandan, değişkenler için etkinlik sıralamasının sonuçları şunu göstermiştir: üç senaryoya göre, asfalt endüstrisindeki şirket sayısı - üretim ve döşeme (x1), en önemli değişken olduğunu gösteren ilk sırada olduğu belirlenmiştir.

Ülkeler için maliyet etkinlik sıralamasının sonuçları; üç senaryoya göre, Slovenya ve Slovakya birinci ve ikinci sırada yer almıştır. Senaryo 1 ve 2'ye göre, asfalt uygulamalarının etkinliğindeki en önemli değişken toplam bitüm tüketim. Senaryo 3'te asfalt endüstrisinde- üretim ve döşeme (x1) şirket sayısı ilk sıralarda yer almıştır.

Sonuçlar

Türkiye ve seçilmiş bazı ülkelerin asfalt uygulamalarını değerlendirmek amacıyla yürütülen bu çalışmada yapılan analizlerden elde edilen bulgular şu şekilde değerlendirilebilir:

- Ülkelerin Gruplandırılmasına göre ÇBÖ analizinden elde edilen gruplandırmanın sonuçlarının kümeleme analizinden daha uygun olduğu söylenebilir.
- Etkinlik analizinde, senaryo 1 ve 2'ye göre, Norveç hariç bütün ülkeler etkindir.
- Etkin olmayan ülkeler için potansiyel iyileştirme önerileri genellikle girdi değişkenlerinden x1 (Asfalt endüstrisindeki üretim şirket sayısı) için azaltma çıktı değişkenlerinden de y2 (Toplam otoyol ve ana yol uzunluğu) artış şeklindedir.
- Etkin olan ülkeler içinde en çok Hollanda referans ülke olmuştur.

- Senaryo 3'e göre (CCR) ve (BCC) sonuçları yaklaşık olarak birbirine benzemektedir. Her senaryoda (BCC) model sonuçları gerçeği daha yansıtabilir.

- Maliyet etkinlik analizinde: üç senaryo'ya göre Slovenya en az maliyet artışına sahiptir. Slovenyayı Slovakya izlemektedir. En son sırada ise İspanya gelmektedir

- Etkin ülkelerin GİA ile sıralamasında senaryo 1'e göre en etkin ve birinci sıradaki ülke İngiltere, senaryo 2 ve 3'e göre en etkin ülke Slovakya'dır.

- Etkinlikteki önemli olan değişkenlerin sıralamasında üç senaryo 'ya göre en önemli değişken x1 (Asfalt endüstrisindeki şirket sayısı)'dır.

- X1'in en önemli değişken ve etkin olmayan ülkeler için en çok azaltma önerilen bir girdi olduğu için ülkelerin asfalt endüstrisindeki üretim şirket sayısının azaltabilmek için müdahale etmeleri gerekir.

- Ülkelerin maliyet etkinlik sıralamasına göre; üç senaryoda en etkin ve birinci sırada gelen ülke Slovenya'dır.

- GİA ile değişkenlerin maliyet etkinlik sıralamasındaki en önemli değişken Senaryo 1 ve 2'ye göre Toplam asfalt üretimidir (X2).

- Y2'nin en önemli değişken ve etkin olmayan ülkeler için en çok azaltma önerilen bir girdi olduğu için ülkelerin asfalt endüstrisindeki üretim şirket sayısının azaltabilmek için müdahale etmeleri gerekir.

- Türkiye etkinlik analizinde, (BCC) modeli kullandığımızda senaryo 1 ve 2 sonuçlarına göre etkin çıkmıştır. (CCR) model sonuçlarına göre üç senaryoda etkin değil olurken en çok Hollanda referans olarak alır ve toplam asfalt üretimin artışı öneri alınır.

- Türkiye maliyet etkinlik analizinde, (BCC) model sonuçlarına göre senaryo 1 ve2'de maliyette etkin çıkmıştır. En yüksek maliyet artışı da senaryo 3'te bulabiliriz. Türkiye'nin yol altyapısı maliyetleri azaltmasını önerebiliriz.

- Etkinlik sıralama sonuçlarına göre, Türkiye senaryo 1 ve 2'de en son sırada gelmektedir

Çalışmada literatüre katkı sağlamak amacıyla, ülke gruplandırmada farklı değişken kombinasyonları bağlamında analizler yapılmıştır. Böylelikle, farklı ülkelere yönelik asfalt uygulamalarına göre yeni bir model sunulmaya çalışılmıştır. Bu modelin, asfalt alanında yapılacak yeni çalışmalara yardımcı olacak nitelikte bir referans olması beklenmektedir.

Asfalt uygulamalarının VZA ile etkinliğine yönelik tek bir çalışma (Li ve ark, 2013) var olduğu için ve aynı zamanda literatürde asfalt maliyet etkinliğini değerlendiren herhangi bir çalışma bulunmadığı için bu çalışmada asfalt uygulamaları ile ilgili yeni bir görüş açısı sunulmak istenmiştir. Bu alanda yapılan çalışmaların çoğunluğu VZA kullanarak yerel asfalt bakım politikalarının incelenmesine yöneliktir. Ayrıca bu alandaki yapılan çalışmalar, daha çok mühendislik kriterlerine göre yapılmıştır. Bu çalışmada ülkelerin asfalt uygulamalarına ilişkin veriler; etkinlik ve maliyet etkinlikleri bakımından analiz edilmiştir. Bu bağlamda tezin asfalt etkinlik ve maliyet etkinlik ile ilgili bulgularının literatüre ve araştırmacılara katkı yapması beklenmektedir.

Etkin ülkelerin ve değişkenlerin sıralaması açısından tez değerlendirilirse; yine literatürdeki çalışmaların çoğunluğunda GİA ile daha çok asfalt ve asfalt karışım kriterlerinin değerlendirildiği görülmektedir. GİA bu çalışmada şu iki neden ile kullanılmıştır: İlki; VZA etkin ülkeler için değil etkin olmayan ülkeler için bir açıdan sıralama sunarken, etkin ülkeler için etkinlik açısından herhangi bir sıralama vermemektedir. Dolayısıyla etkin olan ülkelerin de kendi içlerinde etkinlikleri bağlamında sıralamasının yapılması, özellikle referans alınan (etkin olan) bu ülkeler ile ilgili farklı değerlendirmeler yapılabilmesi açısından önemli olacağı düşüncesine sahip olunmasıdır. Söz konusu etkin ülkelerin sıralaması, GİA ile sağlanmıştır. GİA kullanılmasının ikinci nedeni, etkin ülkelerle ilgili sıralama amacı kapsamında etkin olan bu ülkelerin asfalt uygulama bakımından hangi değişkenlerin daha fazla etkisi söz konusudur? Sorusuna cevap arayışıdır. Yine bu amaca da GİA ile değişkenler asfalt uygulamasındaki önemleri bakımından sıralanmıştır.

Bu çalışma asfalt uygulama bakımından Türkiye ve benzeri ülkeleri etkinlik, maliyet etkinlikleri bakımından farklı senaryolarla inceleyen ve bu analizlerden elde edilen bulgular doğrultusunda gerek ülkeler gerekse değişkenler bakımından önem sıralamaları veren birbirleriyle ilişkili analizlerden oluşan hibrid bir çalışma olarak literatürdeki ilk çalışmadır. Bu tez çalışmasının yöntem, bulgu, değerlendirmelerinin literatüre ve araştırmacılara yararlı olacağına inanılmaktadır.

Öneriler

Bu araştırmada, Türkiye ve Avrupa Birliği ülkeleri için asfalt kaplama uygulamalarının etkinliğini, asfalt kaplamalarla ilgili bazı girdi ve çıktıları dikkate alarak değerlendirmek amaçlanmıştır. Öncelikle Türkiye ve 16 Avrupa ülkesini k-ortalama küme analizi ve Çok Boyutlu ölçekleme analizi kullanarak gruplanmıştık. Ardından, Veri Zarflama Analizi (DEA) etkinlik modellerini kullanarak asfalt kaplama performanslarını ölçmek için bir grup (Türkiye'nin dahil olduğu grup) seçilmiştir. Sonrasında bu ülke grubu için etkinlik ve maliyet etkinlik analizleri yapılmıştır. Son bölümde ise Veri Zarflama Analizi modelleri bağlamında etkin ülkeler ve etkinlikte önemli değişkenler GİA ile sıralanmıştır.

Bilindiği gibi 2020 yılının ilk günlerinde etkisini hissettirmeye başlayan korona pandemisi nedeniyle bütün ülkeler bu krizi yönetmeye çabalamaktadır. Bugün, farklı ülkelerdeki birçok araştırma ekibi, korona virüsünün tedavisine yönelik aşı bulmak için yarışmaktadırlar. İş dünyasında gerçek anlamda biyolojik virüslerle karşılaşılmıyorsa da etkisi gerçek bir virüs boyutunda olabilecek sorunlarla karşılaşılması her zaman mümkündür. 2008 küresel mali krizinden sonra dünya, covid19 pandemisine benzer küresel bir panik geçirmiştir. Bu krizle birlikte dünya küresel boyutta bir finansal krizi yaşayarak tanımış ve öğrenmiştir. Elde edilen deneyim, bu tür bir krizin tekrarlanmasını önleme çalışmalarında önemli olmuştur.

Farklı sorunlara çözüm aramak için çok fazla çaba harcanmasına rağmen, çoğu zaman çözümün uygulanmasında verilerin doğru ya da güvenilir olmaması, uygun analiz tekniğinin kullanılmaması gibi nedenlerle sorun yaşanabilir. Dolayısıyla böyle durumlarda en güvenilir ve uygulanabilir çözüme ulaşıncaya kadar farklı yolların, farklı yöntemlerin deneyimlenmesi gerekebilir. Ancak her durumda koşulların değişebileceğinin unutulmaması, her denemede planlamanın, denetim ve kontrolün sürekliliğinin sağlanması; başka bir ifadeyle etkin şekilde yönetimin fonksiyonlarının karar sürecine yansıtılması önemlidir.

Araştırmalarda da aslında farklı olayların incelenmesi ve analiz edilmesinde teori ve gerçek yaşam arasında bir köprü kurmaya çalışılır. Bu araştırmada, 2016 Avrupa Asfalt Kaplama Derneği (European Union Asphalt Association (EAPA)) raporu verileri kullanılarak, Türkiye ve bazı AB ülkelerindeki asfalt uygulamalarına ilişkin mevcut durum genel unsurlarıyla ortaya konulmaya, bu ülkelerin birbirlerine bu açıdan benzerliklerine göre gruplanmasına çalışılmış ve ülkeler asfalt performansları bakımından incelenmiştir. Araştırmanın sonuçlarıyla teori ve uygulama arasında bağlı olarak da araştırma bulgularının gerçek yaşam için bir köprü kurmuş olması öngörülmektedir. Mikro ve makro düzeyde araştırma bulgularının süreci anlamak ve kendi sistemlerinde uygulamak isteyenlere faydalı olması beklenmektedir.

Bu çalışmada yaptığımız bu tür değerlendirmeler genellikle mühendislik kriterlerine göre yapılır. Ancak tez için araştırmalar yapılırken ülkeler bağlamında onların literatürde yer alan verilerine göre değerlendirmeler yapılmıştır.

- Bu değerlendirmelere göre;
    - Genellikle yüzölçümü küçük ve bu yüz ölçüme göre daha az oranda iş hacmi olan ve daha az firmaya sahip olan ülkelerin daha etkin ekonomik ve maliyet göstermeleri ideal olarak tanımlanmıştır.
    - Bu tür ülkelerde hem yol yapımları hem de bakım faaliyetleri genel yol hacmine göre az oranda görüldüğünden maliyet anlamında da etkin olarak değerlendirilmektedir.
    - Ancak Türkiye gibi dinamik ve aynı zamanda çok fazla çeşit ve hacimde işin yapıldığı ülkelerde, yukarıda sözü edilen değerlendirmeler açısından durumda sorunlar yaşanmaktadır. Türkiye ve benzer yapıdaki ülkelerde yol ve asfalt yapımları birkaç ayrı kurum tarafından yapılmakta, ihtiyaçlar da kurumların iştigal alanlarına göre değişmektedir. Belediyeler şehir içlerindeki yolları yaparken, Karayolları Genel Müdürlüğü şehirler arası yolları, Orman Genel Müdürlüğü orman içi yolları, Turizm Bakanlığı ise turistik yolları yapmaktadır. Bu nedenle de yolların ihtiyacı da o anki şartlara göre

değişmektedir. Bu nedenle Türkiye gibi gelişmesi hızlı olan ülkelerin yol ağlarında sürekli olarak artış görülmektedir.

- Aynı şekilde bir ülkede çok fazla yol firmasının olması da istenen bir durum değildir. Genellikle de firmaların azaltılması için devletlerin çalışmaları vardır. Yol ihalelerinde daha az firmanın iş alabilmesi için ihale şartları ağırlaştırılır. Bu da beklenen bir sonuçtur, çalışmanın sonucunda da bu yönde bir eğilim çıkmıştır.

- Yol inşaatlarının tamamında yaşanan sıkıntılardan biri de altyapı yatırımlarıdır. Altyapıları düzgün yapılmadığı takdirde sürekli olarak bakım maliyetleri artar. Bu durumun yolun ilk yapımı esnasında dikkatlice yapılması gerekir. Bundan dolayı da bu yatırımlar hiç azalmamaktadır. Tez çalışmasında da bu durum ortaya çıkmıştır. Bu konuda Türkiye' de ciddi anlamda çalışmalar yapılmaktadır.

- Avrupa ülkelerinde altyapı yatırımları daha az olmaktadır, çünkü nüfus artışı ve şehirlerin gelişmesi bizim ülkemizdeki gibi olmamaktadır. Şehirler yıllar önce kurulmuş, nüfus artışı da belli oranlarda sabit kalmıştır. O nedenle de altyapı yatırımların sürekli artmasını gerektirecek fiziksel bir durum yoktur. Türkiye gibi ülkelerde bu durumda sürekli hareket olmasından dolayı çalışmada çıkan etkinlik altyapı yatırımları için kabul edilebilir nitelikte değildir.

Anahtar Kelimeler: Yol alt yapısı, Asfalt, Asfalt uygulamaları, Performans Ölçümü, Etkinlik, Kümeleme Analizi, Çok Boyutlu Ölçekleme Analizi, Etkinlik Analizi, Maliyet Etkinlik Analizi, Veri Zarflama Analizi, Etkinlik sıralaması, Gri İlişkisel Analizi

ABSTRACT

COST EFFICIENCY ANALYSIS OF ASPHALT PAVEMENT APPLICATIONS IN ROAD CONSTRUCTIONS ACCORDIONING TO DIFFERENT COUNTRIES

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Each country is under a great pressure to provide its citizens with a good standard for living and welfare. With lots of obstacles surrounding decision making process, each country must do a performance measuring for its different activities. Transport infrastructure plays an important role in ease people and freight mobility especially road transport. In this research, we concentrated on asphalt as one of the most important components of road transport infrastructure. The purpose of this study is to measure asphalt performance for different countries by using efficiency and cost efficiency analysis. Since, different countries might have different attitudes toward asphalt applications, we preferred to use two methods of clustering to group countries which are; Cluster Analysis and Multidimensional Scaling Analysis (MDS). Then, according to analysis results of countries' grouping and by concentrating on the group that involves Turkey as one of its entities, we used out-put oriented Data Envelopment Analysis (DEA) to define efficiency scores for Decision Making Units (DMUs) or countries. In the scope of this analysis, we suggested three scenarios of inputs and outputs. According to three scenarios suggested, we calculated the cost efficiency ratios as well. After that, we performed Grey Relational Analysis (GRA) to rank the efficient and cost efficient DMUs and variables.

Keywords: Road infrastructure, Asphalt, Asphalt pavement applications, Performance Measurement, Efficiency, Cluster Analysis, Multidimensional Scaling Analysis, Efficiency Analysis, Cost Efficiency Analysis, Data Envelopment Analysis, Efficiency ranking, Grey Relational Analysis.

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ABBREVIATIONS

BCC	: Data Envelopment Analysis model introduced by (Banker, Charnes and Cooper (1984).
CA	: Cluster Analysis
CCR	: Data Envelopment Analysis model introduced by (Charnes, Cooper and Rhodes (1978).
DEA	: Data Envelopment Analysis
DMUs	: Decision Making Units
EU-28	: The European Union 28 member countries.
EAPA	: European Asphalt Pavement Association
GRA	: Grey Relational Analysis
MDS	: Multidimensional Scaling

ACKNOWLEDGEMENT

First of all, I would like to thank my supervisor **Prof. Nuray Girginer** who taught me our determination is the key for reaching our objectives. From the first day we met, she was the one who always stand by my side, she encouraged me to be the best in everything I do. There are not enough words to thank her for everything she did to me.

Special thanks to my thesis monitoring committee, **Dr. İbrahim Sönmez and Dr. Ferdi Celikay** for being so supportive all through my thesis preparations. **Dr. İbrahim Sönmez** is an expert in road constructions and specially in the asphalt field. His experience and suggestions helped a lot in successfully completing this research. Also, I would like to thank **Prof. İlyas Şıklar and Dr. Behçet Yalın Özkara** for attending and participating my thesis defense exam.

Also, I would like to acknowledge **Eskişehir Osmangazi university and Yurtdısı Türkler ve Akraba Topluluklar Başkanlığı (YTB)** for giving me the chance to come to Turkey and become a PhD student.

Moreover, I would like to thank all my teachers and friends who helped me all through my Turkish learning period and through my PhD studying period.

Special thanks to **University of Khartoum** for giving me the chance to complete my higher education in Turkey.

All through our lives, we are looking for a partner who can understand us, helps us a lot to reach our objectives and stands by our side, when we are happy and when we are sad, who completes all the missing parts in our personalities and helps us in finding solutions to our problems. **My husband** is my partner who proofed to me such a partner is exist. There are not enough words to thank him for everything he did for me. He and my baby handled my absence very well, I want to thank them for their understanding.

A very special thanks to my **mother, brothers and sisters** who supported me in every step in my life. They were be and will be the family of all times. I dedicated this work to my father may his soul rest in peace.

RESEARCH INTRODUCTION

In 2016, the total investments in road transport infrastructure in EU 28 were about to €69 billion (European commission, 2019). If we are about to consider this amount of money used to enhance road transport infrastructure in EU in 2016, if this amount of investment were divided equally among EU 28 countries; each country will be left up with only €2.43 billion. This number makes us wondering if it is enough to satisfy country's road transport infrastructure development and enhancement needs. Whether, the classification of a country was a developed country or a developing one, it strives to gather money from different resources (i.e. it could be by importing goods and services, taxes and etc).

There are lots of evidence prove the existence of a positive relationship between road transport infrastructure and economic growth (such as Mohmand et al, 2017; Peter et al, 2015; Tripathi and Gautam, 2010). According to these evidences, many countries today are struggling to create and develop a sustainable road transport infrastructure. In which, a developed road transport infrastructure might effect positively on economic growth as we mentioned earlier. Yet, a developed road transport infrastructure cannot be obtained easily. For example, Singapore managed to set a long-term plan for developing and enhancing its infrastructure. If we look at Singapore today and Singapore 40 years ago, we can notice a huge difference. In 2019, Singapore was considered the global leader of the best quality of the overall infrastructure according to Statista website.

On the other hand, the resource planning and allocation are considered crucial in decision making process specially in decisions related to road transport infrastructure, since there are many aspects involved. A decision maker should be well aware of economic situation, types of financial resources, ability of obtaining resources domestically and etc.

"A country might face a bankruptcy"

Unfortunately, if a country does not have the ability to obtain most of its resources domestically, it might face a bankruptcy. Today, many countries borrow their financial needs from different sources such as world bank, international monetary fund and etc, so as to cover the deficit in balance of payment, which is considered an easy way to solve their problems without taking into consideration the consequences of borrowing; the case of Greek government-debt crisis might be a good example for similar situation. Eventually, these countries someday will find themselves in a situation where they cannot fulfil their obligations. Sooner or later, they might face a bankruptcy unless they start to set some correctional plans.

Since an adequate road transport infrastructure might effect positively on country's economic growth. We as research scholars are obligated to study and analyse different factors effect on economy to find the best ways that help any country's economy to grow and prosper. Therefore, we have planned our study in the scope of our general objectives and our analysis objectives.

According to our general objective; firstly, we aimed to define Turkey's position in terms of asphalt pavement applications by measuring the efficiency and cost efficiency of homogeneous group of countries. Secondly, we intended to have a contribution to the literature by presenting a new model dealing with asphalt pavement applications from different perspective. Finally, we determined to use data regarding asphalt pavement for the reason that the asphalt is consider a comprehensive product. The asphalt and the most of the materials used to produce it have their own production processes. In each process different resources are involved; these resources might be considered limited so we need to use them efficiently. in this research we wanted to evaluate the efficiency and cost efficiency of asphalt pavement applications according to different countries.

In the scope of our analysis objectives, we concentrated on asphalt as one of the most important component of road transport infrastructure. We aimed to provide insight into the asphalt pavement performances in Turkey and European Union countries by using efficiency and cost efficiency as performance measures. The reasons for choosing the efficiency and cost efficiency analysis methods to measure asphalt performance are that; first, asphalt production is a process needs gathering input materials from different resources and each one of those resources might has its own production process so measuring the asphalt performance is worthwhile. Second, most of European countries are considered economically developed so when we measure asphalt performance in these countries, the results help us to know about their asphalt pavement practices and whither they operate efficiently (i.e. with less waste of materials, effort, money and etc) when it comes to asphalt pavement applications. Third, while the efficiency is the ability of doing things right, it is actually help in comparing outputs to inputs used in production process which in turn help in knowing the ability of any unit to avoid wasting of materials, efforts and money so when we apply that into our case study of asphalt, the results help us to define the levels of efficiency for each country. Fourth, the overall results of measuring asphalt performance by efficiency and cost efficiency help identifying the efficient and inefficient countries.

Hence, to achieve the research objective, we organized this research to be consist of four chapters. Except chapter 1, in each chapter we used two methods of analysis.

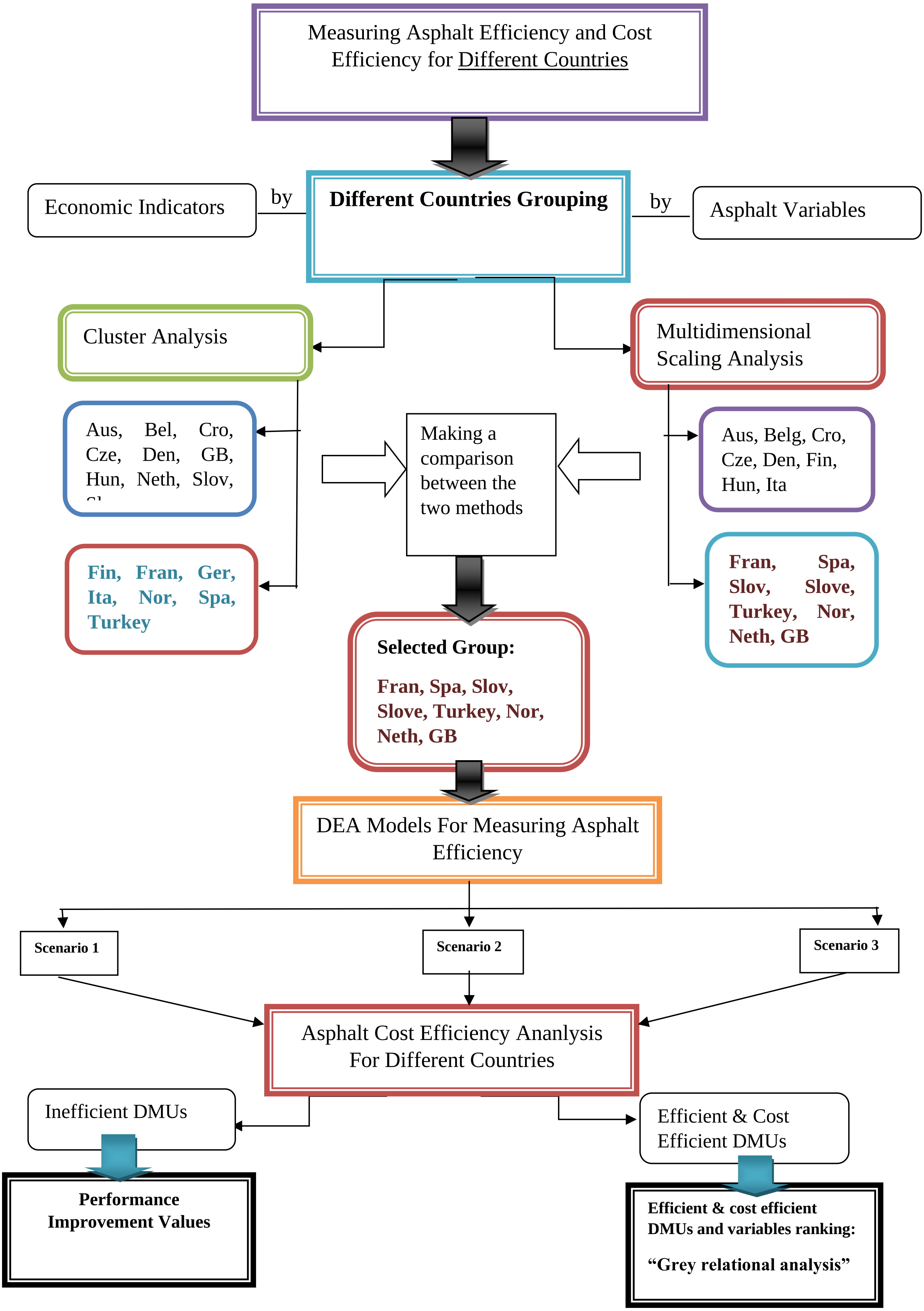
In chapter 1, we conducted a theoretical background discussion about road transport infrastructure and the role of asphalt pavement in it. Also, we discussed asphalt materials, processes and mix types of asphalt. After that, we discussed how to use efficiency and cost efficiency to measure asphalt performance.

In chapter 2, since dissimilarity between countries in terms of asphalt application might give unreliable results, we aimed to start our analysis by clustering Turkey and the EU countries. Hence, by suggesting different variables combinations (consist of all asphalt variable and different economic indicators) we implemented two methods of grouping which are cluster analysis and multidimensional scaling analysis. According to results of this chapter, Turkey was in a group consists of eight countries.

In chapter 3, by taking the analysis results of chapter 2 into consideration, we analysed the efficiency and cost efficiency of asphalt for selected group. In efficiency analysis, by suggesting different scenarios of input and output variables, we used two models of output-oriented data envelopment analysis (DEA) (CCR and BCC). Then, we performed cost efficiency analysis for selected cluster according to different scenarios suggested.

In chapter 4, by taking the analysis results of chapter 3 into consideration, we aimed to define the degree of importance for efficient and cost-efficient countries and variables by using Grey Relational Analysis for each scenario suggested (see the analysis flow chart in Table 1).

Figure 1: The Analysis Flow Chart



CHAPTER 1

THEORETICAL REVIEW OF ASPHALT IN ROAD TRANSPORT INFRASTRUCTURE

1.1. ROAD TRANSPORT INFRASTRUCTURE AND ASPHALT PAVEMENTS

The use of “infrastructure” term can be found in different fields. The word “infra” means a ground or a base, the word “structure” on the other hand is more related to elements distribution (Skorobogatova and Kuzminz-Merlino, 2017).

According to World Development Report (1994), energy, transport, telecommunications, provision of water and sanitation, and safe disposal of wastes are all types of infrastructure services. The different activities done in any community are basically depend on those services. Though, if the infrastructure failed to meet the requirements of communities, the communities’ standard of living and economic growth will be affected negatively. In contrast, an innovated infrastructure services enhances welfare and effect positively on economic growth.

However, the link between infrastructure services and economic growth made a lot of scholars investigating the direction of such a relationship (Cronin et al, 1991; Rauch, 1994; Esfahani and Ramirez, 2003; Sahoo and Dash, 2009; Sahoo et al, 2010; Czernich et al, 2011; Castells, 2017). Actually, infrastructure can be thought as two sides of the same coin. In which it can improve communities’ quality of life and it can effect positively on economic growth.

The road transport as one of the important services provided by infrastructure, can be though as the key element for achieving communities’ welfare. Not by just eases the movements of people and freights from one place to another but also by increasing productivity which in turn effects positively on economy. It can be easy to define road transport infrastructure, but it is not easy to understand the functionality of each of its components completely unless, we divided them and study each one of them separately.

One of the most important and essential components of road transport infrastructure is asphalt. The asphalt was first used by Babylonian in 625 B.C as road building material. From that time until now, asphalt and road-building processes have gained lots of interest. Now, we can find different types of asphalt applied in different situation and for different purposes by using different techniques.

The asphalt is considered a crucial material in road pavement constructions. Whether the use of asphalt was for stablishing new roads or enhancing old ones, the needs of asphalt increases as the demand of it in road constructions increases as well (Setyawan, 2017). Since, the asphalt is resulted from mixing different combination of materials, each one of these materials' prices are subject to market demand and supply which might effect on cost of producing asphalt.

When constructing a road, there are important things that a constructor or decision maker should keep in mind. The length of road that will be paved?, from where pavements should be started and to where should be ended?, which the best asphalt mixture satisfies pavement needs? And many other questions. Answering to these questions can help constructor or decision makers to set pavements plans effectively. Although, a lot of constructors are well informed about these questions and of course their answers but still facing obstacles regarding pavements. The origin of those obstacles might come from the fact that resources are limited and needs are unlimited.

Asphalt does not like any other product in the world. To produce any type of asphalt mixture, lots of effort, workforce, materials and equipment are involved. Nevertheless, the cost of these resources differs according to country's economic situation. Some countries are blessed enough to obtain these resources locally but other countries neither they can obtain them locally nor they have money to outsource them. Thus, Efficient utilization of resources is considered crucial.

In the upcoming sections regarding road transport infrastructure and asphalt, we will conduct historical discussion about road transport infrastructure. Then, we will a closer look at the role of asphalt in road transport infrastructure.

1.1.1. A historical Review of Road Transport Infrastructure

The birth of the road as a formal entity is lost in the mists of antiquity. Most certainly however the trails deliberately chosen and travelled by ancient man and his pack animals were the forerunners of the road as we know it today. As man developed and his desire for communication increased, so inevitably trails became pathways and pathways developed to become recognized travel-ways; no doubt some levelling was done and perhaps soft and marshy patches filled and made firm to ease the movement of man and his beasts of burden.

The invention of the wheel over 5000 years ago made necessary the construction of special hard surfacing capable of carrying concentrated and greater loads than hither fore. That this was realized by the ancients is evidenced by the multiplicity of sometimes sophisticated but more often crude roadways that have been discovered by archaeologists.

The earliest recorded "roadways" was the stone-paved sloping causeway. This causeway was constructed at the direction of Khufu (the Egyptian King Cheops) to ease the movement of the huge limestone blocks that were used in the building of the Egyptian Pyramid.

Moreover, the oldest road in Europe and which might be also called the first dual-carriageway, was the roadway Crete which was constructed about 2000 B.C. to connect Cortina to Knossos.

A third road of constructional interest is the royal processional route in Babylon which was probably built about 620 B.C. the length of this road was about 1220 m long. During building this road, there was a notable material utilization.

These few examples illustrated that road construction had achieved a certain sophistication many thousands of years ago. That the purpose of a road was also appreciated by at least some of the ancients is illustrated by the character of the route known as the Persian Royal Road. This organized trade-cum-military road is believed to have run from Smyrna eastwards across Turkey and then southward through Persia to the Persian Gulf, for a total length of 2400 km. The territory through which it passed was part of the Persian Empire which was then (520-485 B.C.) ruled by King Darius I.

Another who appreciated the importance of the road was the Indian ruler Chandragupta, who in the period 322-298 B.C. constructed a 2400 km road across the sub-continent. This monarch set up a special ministry to organize and carry out maintenance on the route, provide milestones and rest houses, and operate the ferry systems at river crossings. Even then obtaining the finance for road maintenance was a problem and so he obtained a monopoly of the salt trade in order to secure funds to support the roads (O'Flaherty, 1974).

The history of highways can be classified into three major periods. The old roads, modern highway development and future highway development (Oglesby, 1975).

I. The old Roads:

Mesopotamia recordered the appearance of the first hard road surfaces about 3500 B.C. Even before 1500 B.C., there was a stone surfaces road built in the island of Crete in Mediterranean Sea as mentioned earlier. Also, there was evidence proof the existence of road systems constructed by the Mayan, Aztec, and Incan people of Central and South America in the Western Hemisphere.

By using extensive system of roads, the Romans were be able to bound their empire. One of the most interesting example of early roads construction is Appian Way in 312 B.C.. It illustrates the road pavement procedure conducted by the Romans. At first, they excavated a trench to such a depth that the finished surface would be at ground level. Then, they placed the pavement according to three courses: the first course was a layer of small broken stones; the second course was a layer of small stones mixed with mortar and firmly tamped into place; and the third course was a wearing course of massive stone blocks, set and bedded in mortar. Lots of roads constructed by using Appian Way are still exists after 2000 years.

The road building turned into under-apricated skill Roman Empire collapsed. In France Tresaguet (1716-1796) developed an innovated road building strategies. Later on, these strategies helped Napoleon to made conceivable an incredible arrangement of French streets. In England on the other hand, roadways advancements were exceptional especially on MacAdam roadways (1756-1836).

Despites the fact that there was a noteworthy road constructing during that time, same as in England before eighteenth century for example, The establishments of English and American road lines law or rules were being laid. For example, the Early Saxon laws forced on all terrains a commitment to per battalions and help in repulsing intrusion.

II. Modern highway development

The classification of the period since 1920 likely could be as a "vehicle age" during this period street in America has observable and a persuasive job in road transport. This period can be delineated as "an idea on wheel".

Although, street and road mileage have expanded moderately small during these four decades. This small growth is a result mainly of new roads and streets in areas where land use has become more intensive, what's more, from a generally little mileage of significant courses on new arrangements. The best effect of the colossal development in interstate transportation has been to create a considerably more concentrated utilization of a similar street and road skeleton. Thus, the main part of interstate uses to date has gone to adjusting existing streets to this increasingly serious use by incredibly improved vehicles.

The initial 15 years of modern highways improvement saw roadways organizations concentrating on the finish of a system of good country streets similar to the road frameworks embraced by governments. In 1935 the travel between states via vehicle become a practically possible. Since 1935, efforts have been exhausted to develop a high-quality interstates roadway. During a similar period, expanding consideration has been given to urban zones, which have been struck all the while by quickly expanding population which led to a focus change from mass transportation to the private car.

III. Future highway developments

During the modern age developments, the roadways innovation has been extraordinary and it keeps evolving until today. Now, there is a massive information about different fields and types of soils and other pavement materials which made the design process of road construction to be increasingly practical and reliable. The road constructors have come up with ideas on how to construct a safe and proper road. Although, the existence of new sciences in the fields of roadway management, and traffic control helps in stablishing the roads as we know it, there are still a numerous difficulty surrounding road constructing.

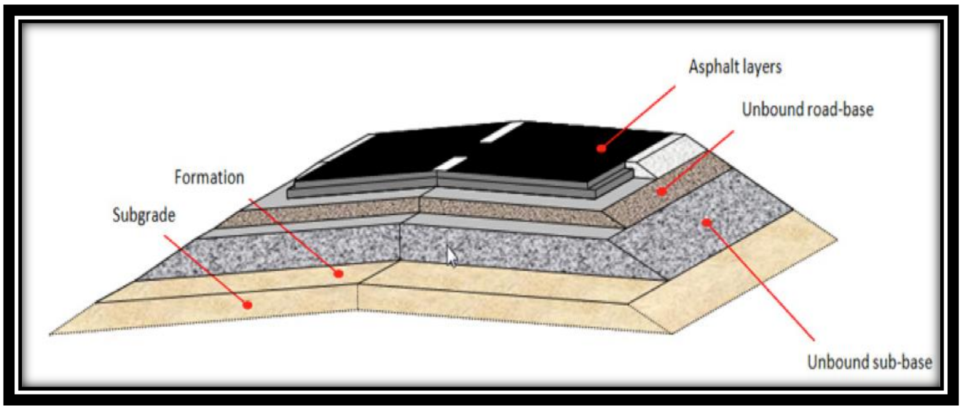
1.1.2. Asphalt Pavements in Road Transport Infrastructure

If we are about to consider asphalt linguistic definition. Oxford Dictionary characterizes Asphalt as a thick dark clingy substance utilized particularly for making of highways. Likewise, Cambridge dictionary defined it as a dark clingy substance, frequently blended in with little stones or sand, that frames a solid surface when it turns out to be hard.

European asphalt pavement association characterizes asphalt as a blend of aggregates, cement, utilized for building and enhancing all sort of streets. Typically, asphalts are made of various layers as it introduced in Figure 1.1. Figure 1.1 shows the various layers of asphalt which comprise of – from down to up – subgrade, arrangement, unbound sub-base, unbound street base and black-top layers.

European asphalt pavement association defines asphalt as a mixture of aggregates, binder and filler, used for constructing and maintaining all kind of roads, parking areas but also play- and sport areas. Normally, pavements are made of different layers as it presented in Figure 1.1. As shown in Figure 1.1 the first layer from the top is asphalt layers and the last layer is subgrade layer.

Figure 1.1: Different Layers of Pavement



(source: EAPA)

After we discussed the asphalt definition from different perspectives, now we need to know about the advantages or benefits of asphalt pavement.

Benefits of Asphalt Pavements

European Asphalt Pavement association (EAPA) described nine benefits of asphalt pavements. There are;

1. **Smooth and Comfortable:** The asphalt is designed and constructed by using techniques that ensure the smoothness and comfortability of all the kind of roadways especially airports runways.

2. **Cost Reduction:** Some of asphalt materials such as reclaimed asphalt which contains a lot of bitumen, can simply be reheated and reused. When the price of bitumen -which is the most important component of asphalt- rises, the reclaimed asphalt become a valuable raw material. Hence reusing reclaimed asphalt produces extensive reserve funds. In this way, the cost of mixing and constructing asphalt that contains a reclaimed asphalt is considered more less than the cost of mixing asphalt without using reclaimed asphalt in the process.

3. **Safe:** The innovative road construction methods guarantee quick dispersal and waste of surface water which helps car drivers to be able to drive in special circumstances such as rain. Thereby, under such circumstances the risk of vehicle sliding will be minimized.

4. **Durable:** Asphalts are frequently constructed utilizing thick base courses for bearing the primary burden over an unbound granular layer. The pavement layers are designed to last for many years. Even enhancing old roads may add to its life.

5. **Fast to construct and maintain:** Asphalt handling and reestablishing can be done very quickly. This is considered crucial especially for general highways enhancements for broadening the lifetime of the highways, giving a convenient and smooth roadway for vehicles.

6. **Totally reusable:** Today, asphalt can be made from a totally reclaimed asphalt. Reusing reclaimed asphalt minimizes the demand of new bitumen.

7. **Elasticity:** the asphalt elasticity or flexibility helps in the adjustments of constructing roadways according to traffic loads and weather conditions.

8. **The green pavement:** Recycling and reusing of asphalt can be considered environmental actions. There is no evidence proof that the machines used in pavement might be harmful to environment

9. **Fuss reduction:** Utilization of asphalt highway surfaces can essentially decrease fussiness. In general, if noise or fuss decreases car accidents decrease as well. Thereby, asphalt is customized to provide the minimum noise level.

1.2. THE ASPHALT PRODUCTION PROCESS

Asphalt pavement or flexible pavement is considered the most dominating type of surface pavement in the planet. There are a wide range of asphalt utilizations, for example, it can be used to pave highways, parking areas, bicycle ways and air terminal runways (Asphalt Institute, 2014).

As there are numerous sorts of asphalt pavement structures available, there are distinctive strategies for planning and designing the thickness of every component in any pavement. Essential to each plan are: traffic stacking (volume and weight), soil-support ability or capability and the specifications of aggregates and asphalt materials. (Asphalt paving design guide (apai), 26.10.2019):

The purpose of this section is to take a closer look at the essential asphalt materials and to present the production process related to each one of them. Also, to have an idea about the three major types of asphalt mixtures.

1.2.1. Asphalt Paving Materials and Processes

Mixing aggregates with asphalt or bituminous materials the most widely recognized pavement method being used today. For example, this mix is utilized on a wide range of roadway-from different layers of concrete on the most noteworthy class of streets to thin. Bituminous materials (bitumen) can be defined as a hydrocarbons, which are solvent in carbon disulphide. They are generally genuinely solid at typical temperatures. If they are exposed to high temperature, they become a dissolved and melted. Also, if they are blended in with liquid aggregates, and afterward exposed to cool temperature, they can set and tie the aggregates together. There are an important aspects of asphalt paving materials that can be clarified in some points as follows (Atkins, 1997);

I. In pavements, the utilized bitumen might consist of; native asphalt (i.e. can be founded in asphalt lakes), rock asphalt (i.e. can be founded in rock stores), tars (i.e. resulted from coal refining) and petroleum asphalt (i.e. resulted from raw material refining) clearing include:
II. Defining different grades or degrees of asphalt materials and temperatures at which they are utilized, relies totally on their consistency or viscosity.
III. Asphalt binder or cements, liquid or fluid asphalts and asphalts emulsions are considered the essential paving items.
IV. Three kinds of hydrocarbons can be used to create asphalt binder or cement, which are asphaltenes, resins, and oil.
V. Viscosity, ductility, thin-film oven test, solubility and flashpoint are all examples of quality control test types for asphalt materials.
VI. Traditionally, asphalt binder or cement grades and specifications were based on penetration grades. Until a new performance-based grading system has been developed. This new grading system suggested specifications and tests for asphalt binders and asphalt mixes have been published for Superior Performing Asphalt Pavements (Superpave™) (Superpave™ is a trademark of Strategic Highway Research Program).

1.2.1.1. Asphalt Concrete

Asphalt concrete can be described as a blend of rough aggregates, fine aggregates and filler. The mixing process done in a binder machine with high temperature degree (Setyawan, 2017; Departeman Pekerjaan Umum, 2008).

The "blacktop" or "hot mix" or "asphalt" used on most roads and on some parking lots is called asphalt concrete. Durability, stability and safety of roadways surface has to be obtained using asphalt concrete. The quality of asphalt concrete components such as aggregates, asphalt binder or cement, construction process and the selection of mix design, guarantees the achievements of above-mentioned properties of asphalt concrete (Atkins, 1997).

1.2.1.1.1. Asphalt Concrete Mix Design

Asphalt concrete designing process begins with determining the best aggregates mix and the ideal asphalt substance. Defining which kind of materials will be used in mixing process, helps in gathering and obtaining the required materials exactly as they were specified. The steps of asphalt concrete mix design can be summarized as follows (Atkins, 1997):

1- Choosing the required amounts of aggregates according to specifications.
2- Performing trial mixes at a range of asphalt substance to measure the results of samples.
3- Conducting a result analyses to gain the ideal asphalt substance and to define wither the specifications were met.
4- Iterating with extra trial mixes utilizing different aggregate blends, eventually the suitable design will be reaches.

The two most common traditional methods for making and evaluating trial mixes which are; the Marshall and the Hveem methods. Recently, the Superpave™ method, introduced by Strategic Highway Research Program (SHRP) is most likely being preferred.

1.2.1.1.2. Asphalt Concrete Production and Paving

After reaching and selecting the most satisfactory blend or mix design, the process of producing the mix starts. At this point, the process of producing the mix is accomplished in an asphalt planet. There are five segments of asphalt planets which were being utilized traditionally. Such as; cold aggregates stockpiling containers, a dryer, grading and screening unit, hot stockpiling containers and a pug grinder for blending. The activities done on those segments can be summarized as follows (Atkins, 1997);

A surge bin or stockpiling containing the mixed asphalt is sometime included as part of the plant to store the material until it can be placed into trucks. Also, there are storage silos which used to store large volumes, can save the mix or blend for various days without genuinely spoil its characteristics. High temperature and oxygen removal are required to maintain silo and to prevent oxidation of the asphalt cement.

After the aggregates have been consolidated in the dryer and isolated again by size in the graduation unit over the hot containers, the proportion required from each hot container or bin must be set up. Amounts required from each hot container are estimated into the pug grinder by scales in group plants and by change of hot-bin doors in ceaseless plants. Additionally, the amount of asphalt cement and mineral filler or any other added substances, whenever required, must be set up.

The steps in production are effectively reduced from four (cold feed, drying, hot graduation, mixing) to two (cold feed and drying-mixing) as follows:

1. Cold feed bins or containers used to store the aggregates. Scale control the amount of material from each bin to ensure that the correct proportions are maintained.
2. Aggregate enters the drum. Drums in these plants have the burner located at the aggregate entrance end rather than at exit end as in other plants. As the aggregate enters and proceeds through the drum, the following occurs:
   a. Surface and free moisture is evaporated
   b. The temperature of the aggregate is raised to 75-80^{o}C(170-180^{o}F).

c. Asphalt cement is introduced. The aggregate is now at 80-90^{o}C (180-200^{o}F). The moisture that is driven off causes the asphalt to foam, trapping dust particles and engulfing the aggregates.
d. Further mixing occurs and the temperature is increased to the specified level.

The amounts are constantly controlled automatically in many plants as a result of quality control. Quality control also helps in recording the proportion of aggregates entering the drum. The proportions of asphalt cement being brought into the drum is automatically changed according to the proportion of aggregates. Moisturizer substance of the aggregates quantities is entered to the drum. Temperature of the mix leaving the drum is constantly assessed and the burner is designed to adjust temperature automatically so that the mix temperature can be kept in the acceptable range.

Surge bins or silos are typically utilized with drum plants to take into consideration different paces of transportation of the mix and to help control conceivable isolation. Drum plants for the most part have higher production rates (as much as 5000 tons or 5500 tons for every day) than traditional plants.

After asphalt concrete being transferred into construction site, the concrete is paved and rolled. must be laid, wrapped up by the paver, and rolled. In addition to grade and thickness prerequisites, The major aspects of quality control are;

1. Temperature: there must be a minimum temperature at the paver to ensure that the concrete can be compacted and that aggregate particles can be worked into the requisite dense, strong structure.
2. Compaction: the layer must be compacted to meet specifications, usually expressed as percentage of the laboratory density.

1.2.1.1.3. Inspection and Quality Control of Asphalt Concrete

The inspector of the highway agency is required to test, examine and to do quality control over the asphalt plants and road construction site. He must be well informed of operations and controls that govern mix proportion and temperatures in asphalt plant. Same essential aspects should be checked approximately every day, such as; aggregates stockpiling, material graduation in hot containers, proportion system, temperature of each component, dryer and mixer operations and the mix quality after it delivered on trucks (Atkins, 1997):

A variation in the mix or inadequate mixing can only be revealed by doing a visual examination of the finished mix. The material might shape peaks in the truck, if the mix was lean that is mean it contains too much fine aggregate, or not enough asphalt. If the mixture flattens out (it is “fat”) that is mean it probably has too much asphalt or too high a proportion of rough or coarse aggregate.

After we discussed asphalt concrete and as asphalt cement and aggregates are the essential components or materials of asphalt concrete, having a closer look at each one of them is worthwhile. Thus, in the upcoming sections we will discuss the production processes of both asphalt cement or binder and aggregates.

1.2.1.2. Asphalt Binder/Cement and production process

One of the major components of asphalt concrete is called asphalt cement or binder. The asphalt cement has the same characteristics of normal cement, it is used to adhere aggregates together. It can be obtained from petroleum refining same as gasoline and other petroleum products. Asphalt cement is mainly produced from thick and heavy residuals results from petroleum refining (Speight, 2015).

There are numerous elements depend on utilizing the added substances of asphalt cement or binder such as capacity, cost and other elements. The reason behind utilizing the added substances is to improve the execution of asphalt pavement, also to diminish asphalt pavement disorders (like moisture damage for example) (Zangena, 2019).

The crude oil is considered the major component of asphalt cement. The asphalt cement production process begins with refining and differs according to different types of asphalt cement. Thereby, the asphalt cement production process or procedures according to different types of asphalt cement, can be summarized as follows:

1. **Refining procedure**

The refining procedure is accomplished by pumping crude oil into refinery. At this stage, the crude oil will be taken from stockpile through tube heater which designed to raise crude temperature immediately so that it can be refined. After that, the crude oil is moved is moved into atmospheric refinery to totally remove any unwanted components. This step is followed by additional refining to isolate the other products of crude oil such as diesel and gasoline.

The topped crude which is the thick leftovers from atmospheric refining, is additionally processed to give other products such as asphalt. Sometimes, the topped crude might consist of low volatile materials which can not be isolated through refining, in this case a dissolvable extraction is highly recommended to produce asphalt binder or cement.

2. **Mixing Procedure**

The mixing procedure is related to adding a cutting back agent or volatile substance into asphalt mixture and blending them together. After this procedure, the product become softer and manageable not so like pure asphalt binder or cement. At this point, utilizing asphalt for paving purposes moves the volatilized or unstable components after it is exposed to air for example which give the hard asphalt binder.

3. **Emulsion Procedure of Asphalt**

The fluid asphalt binder or cement can be blended with aggregates or handled through channels easily. The fluid or liquid asphalt cement can be obtained by emulsifying the asphalt cement. In order to do so, the asphalt cement is balanced to be about (5-10 microns, i.e. one micron is considered to be equivalent to one millionth of meter). After that, it will be blended in with water and emulsifying substance. The emulsifying substance minimizes the propensity of asphalt and colloidal clay can be one example of it.

4. **Grinding Procedure**

A powder asphalt can also be obtained by smashing and grinding the asphalt. For pavements, it is utilized by blending it with aggregates and oil. The powder asphalt can be merge with aggregates and restricting oil to be exactly as the original asphalt binder.

5. **Oxidization Procedure**

Asphalt can also be oxidized to be utilized for other reasons than road pavements such as a pipe cover. The oxidization process can provide a smooth material, if those materials exposed to a higher degree of temperature not so like the temperature used for asphalt pavement.

1.2.1.3. Aggregates and aggregates production process

The tiny pieces of grainy minerals are commonly referred to aggregates. It can be utilized by blending it with different kinds of solidifying materials to shape cement or binder, or it can be utilized without additives as street bases or a refill and so on. Asphalt concrete and road bases can be examples of the major regular employments of aggregates (Atkins, 1997).

Aggregates consists of cruel rigid materials (such as; squashed stone, slag, rocks or rock dust). For pavements shaping, aggregates are blended with asphalt cement or binder. Aggregates are considered the most supportive material of asphalt concrete, it might be about %95 of the mixture or blender by weight (Asphalt Paving Design Guide, 2014).

There are three major classifications of aggregates to be utilized in asphalt concrete mixture, such as mineral filler, coarse or rough aggregates and fine or soft aggregates. The use of fine aggregates are significant in creating a thick graded and solid materials, usually a mineral filler is utilized to support fines. Numerous of genuine sands do not consist of the sum or sort of fines required for pavements so sometimes it is needed to be adjusted according to different requirements (Atkins, 1997).

In order to be well aware of the aspects of aggregates production, we need to discuss the aggregates production process. The state of Indiana official website in one of its publications gave a detailed discussion of aggregates production process. Thereby, the production process of aggregates can be summarized as follows;

1. Extraction

Most of materials utilized in aggregates production come from rock and sand holes or pits or from mined quarries, except for slag and other produced materials of aggregates originates in substratum or bedrock. The quality of extractive materials depends totally on technique used for extraction.

The initial step of extraction begins with assigning a point by point stripping system for every one of mined stores. This step is considered very crucial because it can affect on the quality and inconstancy of materials.

There are two problems related to quarry administrators. The first one is that the quarry administrators do not consider the quality of materials, while ordinarily planning for shatter shots. The second one is the hardness of providing unified burden from either the shot stone heap or the rock bank. a sophisticated operator is significant to ensure having a well-defined material from shot operation.

2. Crushing

After aggregates materials extracted from quarry, the crushing operations start. The purpose behind crushing operation is to diminish and size the materials. In some cases, scalping procedure is preferred before crushing operations. Scalping procedure regularly is utilized to occupy fines at a jaw essential smasher so as to improve smasher effectiveness.

Three kinds of crushing are applicable; the first one is elementary crushing, the second one is secondary crushing and the third one is impact crushing

a. Elementary crushing

Elementary crushing might be considered as the first step of crushing. The reason behind conducting an elementary crushing is to diminish the size of massive material by using a compression smasher or crusher. The compression smashers or crushers can make slender and prolonged molecules with a low cost, but in some cases the impact smashers or crushers are utilized for elementary crushing purposes. The cost of using impact smasher is relatively higher than the cost of using compression smasher. Though, the low-quality aggregates can be only adjusted using impact smasher.

b. Secondary crushing

The final step of diminishing the material into acceptable size is secondary crushing. In the past, the cone and roll smashers or crushers were the most preferred smashers, yet lately the impact smashers become broadly utilized.

c. Impact crushing

Regardless of having to some degree higher operational cost than other different smasher, the impact smashers or crushers might be utilized as elementary or secondary smashers. The reason behind preferring this type of crushing is that, the impact smashers have the ability to make a progressively uniform molecule shape which might influence on aggregates positively.

3. Screening

There is a continues need for screening in any process. In aggregates production process, screening is a strategy to control and grade the aggregate (i.e. in this case aggregate is the product under consideration). Screening helps in identifying and eliminating the existence of undesired elements. It might be used between smashing or crushing to readjust material sizes into acceptable range.

4. Isolation or Segregation

The segregation is important to isolate different items from each other. There are two types of segregation. The first one is called front to back isolation or segregation and the second one is called roll down isolation. The first one is conducted in a belt where fines become in the base and coarse or rough aggregates stays in the top, during this process any un-diverted items are discarded out. The second one, happens when aggregates are heaped with the goal that huge molecules or particles roll down the inclined side of the heap.

5. Storing and handling

Storing or stockpiling and handling are crucial for preserving the quality of aggregate until it is used properly. The poor storing and handling might negatively effect on different characteristics of aggregates before utilizing them. There are different types of storing and handing dealing with different kinds of materials used to produce aggregates.

6. Breakdowns

Most of breakdowns or degradations occur on aggregates are mainly related to storing or stockpiling. In this case, the corrupted heaps must be disposed before products loading into trucks. A comprehensive examining and testing are significant to define which kind of materials is not adequate to be dispatched.

7. Pollution and Contamination

The indifference behaviours related to materials storing or stockpiling are the major reason for pollution or contamination. In some cases, various materials are stored near to each other in the same place which might led to serious problems related to stockpiling. The old heaps might be more exposed to contamination than new ones.

1.2.2. MIX TYPES OF ASPHALT PAVEMENTS

The asphalt mixes or blends can either be hot, warm or cold. Each one of those mixes has different production process along with different temperature adjustments.

1. Hot mix asphalt (HMA)

The hot mix asphalt is the one of the most utilized asphalt mixtures in pavement constructions. After the preparation of asphalt blend ends, the asphalt blend or mix is then exposed to a high temperature may be about (300-350 ºF).

There are different kinds of hot mix asphalt used for different purposes. For example, the thick graded mix which depends on the texture of utilized aggregates (i.e. the thick graded mix can be either fine or coarse graded). The thick grades mix is commonly utilized in paving the highways with high traffic volume. Another example is stone or gravel matrix asphalt which requires a large portion of cement or binder to produce it. This kind of mix is considered somewhat more costly than other kinds. It is utilized in pavement to eliminate rutting and to prevent vehicles from rolling over, in another ward it ensures the stability of tires on highways.

2. Warm mix asphalt (WMA)

This sort of asphalt mix or blend is exposed to a relatively cooler temperature than hot mix asphalt, it may be about (200-275 ºF). The production process of warm mix asphalt involves utilizing an added substance or performing a frothing method. Utilizing the warm mix asphalt in pavements has many advantages, for example;

producing this mix decreases the fuel consumption and decreases the harmful emission of using petroleum products which effects positively on environment. The warm mix asphalt might be utilized for street paving at any time of a day.

3. Cold mix asphalt

The cold blend or mix asphalt is basically consumed for fixing roadways' ruts and holes. The production process of cold mix asphalt starts with emulsifying procedure before it is actually blended with aggregates, this procedure ensures the smoothness of asphalt without using heaters. The cold mix asphalt may be applied directly into ruts and holes without any additional procedures.

1.3. PERFORMANCE MEASURING OF ASPHALT PAVEMENTS

If we want to consider the linguistic form of performance, Cambridge dictionary takes performance to be as how well a person, machine, etc. does a piece of work or an activity. Although, there is no standardized or uniform definition for performance. Sonnentag and Frese (2002) have introduced three alternate points of view on performance; the first one, contrasted singular view point looks for singular qualities such as attitudes. The second one, a conditional point of view emphasizes on conditional angles. The third one, a performance coordination point of view which depicts the performance procedure. Those three points of view help in approaching the performance from various aspects.

Interoperability Clearinghouse Glossary of Terms characterized the performance as the way toward creating quantifiable pointers that can be methodically followed to evaluate progress made in accomplishing foreordained objectives.

Moreover, Behn (2003) presented a model contains eight purposes for measuring performance by defining questions that answering them can help the public managers in performance measuring process. The suggested questions depended on eight major points which are; Evaluate, control, budget, motivate, promote, celebrate, learn and improve. He pointed that those questions are the purpose for performance measuring. Also, for each purpose he defined the characteristics of performance measure.

In the next sections, we discussed how can we measure the asphalt performance by efficiency and by cost efficiency.

1.3.1. Measuring Asphalt Performance by Efficiency

Lately, efficiency has gained a lot of interest. The world battles to suit the tremendous increase in population and to deal with the distribution of limited resources among these population which led to a huge need for efficiency measures (Archer, 2010). If we considered the linguistic meaning of efficiency, Dictionary.com has characterized it as; the state or nature of being efficient, or the readiness to achieve something with minimal dissipation of time and exertion; or the competency in execution. The business dictionary likewise characterized it as; The assessment of what is really created or performed and what can be accomplished with a similar utilization of resources such as labour, financial resource and etc. Point the fact that, efficiency is considered a significant factor in determining the productivity.

Productivity in production process inspects the connection among inputs and outputs. thereby, to measure the production activities using productivity, it can simply be interpreted as a ratio as follows;

$$Productivity = \frac{outputs}{inputs}$$

In another word, it is the expression of acquired outputs in comparison with utilized resources (Jayamaha and Mula, 2011; Coelli,Rao et al. 1998).

Measuring productivity and efficiency through establishing a framework at the small-scale levels, was first introduced by Farrell (1957). In his framework, he defined two primary focuses; the first one was identifying the meaning of productivity and efficiency, the second one was figuring the standards that measure the productivity. The principal supposition of this framework was that of an ideal input to output portion that permits the inefficient tasks or operation. Inefficiency measures the farness of a firm from a frontier production function[1]. The firm is efficient, if the real production point located on the frontier, and it is not efficient, if the real production point located below frontier. The level of efficiency for Decision Making Units (e.g. firms, countries, etc) can be express as a ratio of the actual or real to potential (Jimborean and Brack, 2010). The value of efficiency ratios can be somewhere in the range of zero and one, where the perfect efficiency is demonstrated by one (Fiorentio et al, 2006).

[1] Frontier production function can be defined as the superior outputs portions that can be accomplished by a firm with the utilization of a given available inputs or resources.

On the other side, asphalt pavement not like any process in the world, it is complicated, and it needs dedication and support. Each step needs to be well planned and organized to have a good utilization of the resources. Thus, to ensure the sequence of this process, the performance of asphalt pavement needs to be evaluated.

A performance evaluation of asphalt design and asphalt mixtures have been addressed in many researches such as (Choubane et al, 1999; Asi, 2007; Zhao et al, 2007; Lee et al, 2007; Liu et al, 2009). Other research scholars have gone beyond evaluating the asphalt and asphalt operations into evaluating the performance of highways such as (Liu et al, 2006; Sharma et al, 2013).

1.3.2. Measuring Asphalt Performance By Cost Efficiency

In general, the cost efficiency measures the distance of production costs for one firm from the production costs of the best practice firm producing similar products. The production costs of decision-making units (or firms) in one sample contribute in figuring the cost function. The cost function denotes the total production costs for one firm as the price of inputs. It permits the estimation of the lowest cost portion of inputs with regard to input prices (Ashton,1998).

In asphalt pavement in particular, cost plays an important role. In asphalt pavement, we can find costs related to inputs like cost of getting or producing materials, costs related to asphalt production process and so on. Since, resources are scarce we need to produce asphalt with least waste of materials and efforts. Here comes the importance of efficiency measures. By using cost efficiency analysis, decision makers can know if they were operating efficiently or not. If not, which kind of actions that they have to go with in order to be perfect efficient.

Unfortunately, there are a considerable number of researches used the cost efficiency to measure asphalt. These researches preferred to assess cost efficiency of asphalt materials rather asphalt as whole. For example, some of them assessed aggregates cost efficiency (Athanassopoulos and Triantis (1998); Banker et al (2007).

CHAPTER 2

TURKEY AND EUROPEAN UNION COUNTRIES' GROUPING IN TERMS OF ASPHALT PAVEMENT APPLICATION USING CLUSTER ANALYSIS AND MDS ANALYSIS

2.1. INTRODUCTION

In the previous chapter, we discuss the theoretical part of road infrastructure, asphalt and asphalt pavements. This chapter is considered the first chapter regarding our research analysis.

Each country has its own characteristics which might be similar or dissimilar to other countries. In asphalt pavement applications for example, each country has its own policies and procedures, but if we want to evaluate the performance of asphalt for each country, then we need to compare its performance with other similar countries performances. If we about to consider Turkey, it has a strategic location in which it links Asia to Europe. When we compare Turkey's performance in terms of asphalt pavement applications with other Asian or European countries, we might base our comparison in strong ground. In which, Turkey might share the characteristics of both Asian and European countries. Hence, in this chapter we aimed to classify Turkey and European Union countries according to their asphalt pavement applications as a start point for our further analysis in the next chapters. In order to do so, we need to conduct a brief discussion about the importance of countries classification.

In order to clarify the importance of classification clearly, we need to tell a brief scenario about identical twins. In case of meeting identical twins, first thing comes to mind is of course knowing their names, then trying to define the differences between them to be able to recognize them next time you meet those twins. Identical twins might have same eyes, same nose, same face shape but different attitudes. Some people might even recognize them according to their attitudes. In another word, they might have a similar appearance but dissimilar personality.

Now, by applying the identical twin's scenario into countries classification scenario, we can emphasize on the importance of classification. When we classify countries in terms of any exact topic into groups according to similarity and dissimilarity, we can find that according to their similarities; they are located in one group, and according to their dissimilarities; they are located in different groups. In another word, when we classify countries into clusters, we strive to find similarity and/or dissimilarity between them so that we can understand the behaviour or attitude of each cluster which in turn makes the process of studying and analysing those group much easier.

The importance of classification relays on the fact that when we aimed to study some sample as a whole without taking into consideration the differences between objects in the same sample, the results of this study might not be a reliable at least in some cases. So, when we classify objects into groups according to similarity and/or dissimilarity between them, we can be able to study each group separately and obtain a reliable result that can be generalized.

In this chapter, we aimed to classify Turkey and European Union countries into groups in terms of asphalt pavement applications by using two methods of clustering which are cluster analysis and multidimensional scaling analysis (MDS). Each method can classify countries into clusters according to similarity and/or dissimilarity between them in terms of asphalt pavement applications. At first, we analysed the data of different variables combinations by using k-mean clustering method. Then, we analysed the data of the same variables combination by using MDS method. Afterwards, we conducted a comparison between the analysis results of the two methods.

2.2. LITERATURE REVIEW

There are around 200 countries on the planet. These 200 countries might differ in each possible feature such as; language, geographical location, religion and so on. Although, studying and elaborately describing those countries separately are considered difficult, time consuming and in most cases are not possible. Researchers and government authorities define a simply way that helps studying those countries effectively, which is clustering or grouping the huge number of countries into smaller groups or clusters (Smit et al, 2008).

We can find many research examples used cluster analysis as a method to define similarity and/or heterogeneity between countries. Kuşkaya and Gençoğlu (2017) the target of their examination was to analyze the OECD countries' position with regard to anthropogenic greenhouse gas emissions. To achieve their target, they performed a comparison between 31 countries' emission values for twenty years period of time (1995-2015). The data of their study were based on data obtained from OECD Stat concerning the greenhouse gas emission. The used indicators such as carbon dioxide, hydro fluorocarbon, methane, nitrogen oxide, per fluorocarbon and sulfur hexafluoride emission, to conduct a Ward method of cluster analysis. In accordance with analysis results, they obtained four clusters for each two years from 31 countries suggested. In general, the environmental and climate policies and implemented the obligations of their international contracts made some countries to be gathered in the same group.

Gençoğlu and Kuşkaya (2016) the purpose of this study was to investigate the countries' state regarding gender mainstreaming. They examined 38 European and Middle Eastern states dependent on the data of one year (2015), obtained from the Global Gender Gap Index (CCGI) arranged by the World Economic Forum (WEF). To perform a Ward method of cluster analysis, they used economic, political, education and health variables for each country under examination. Regarding the results of cluster analysis, 38 countries were divided into six clusters concerning the gender gap. In addition, they pointed that countries with GDP salary per capita level near to each other, were located in the same cluster.

Michinaka et al (2011) aimed to group 180 countries considered in the Global Forest Products Model (GFPM). They utilized a cross-sectional data for per capita gross domestic product (GDP), forest coverage, and per capita consumption of forest products, for forest products including plywood, particleboard, fibreboard, newsprint, printing and writing paper, and other paper and paperboard. The use of cluster analysis in advance helped to solve the issue regarding estimating elasticities by countries' grouping depending on variables recognized from economics theory and to allow for the extension of elasticity estimates to countries that located in the same group. They utilized mean absolute deviation for data standardization, and the k-medoids approach and silhouette technique in cluster analysis. Results showed different combination of clusters for each forest product with the same levels of per capita GDP, forest coverage, and consumption. They approved that the consequences of the cluster analysis by a single direction means examination and multiplied comparisons. Likewise, they chose countries for panel data investigation dependent on time series data availability. In this further investigation, they evaluated long-run static models, short-run dynamic models, and long-run dynamic models of panel data analysis for each cluster, from 1992 to 2007 and 9 to 44 countries. They found out that the long-run dynamic elasticities are higher than short-run dynamic estimations, and dynamic model estimations outperform static model estimations as shown in RMSE statistics.

Tsangarides and Qureshi (2008) analyzed the appropriateness of countries in the west African region to shape the proposed financial associations such as; the West African Monetary Zone (WAMZ) and the Economic Community of West African States (ECOWAS). Their examination showed that, there were significant dissimilarities between member countries in terms of economic qualities, especially WAMZ countries. Moreover, when they analyzed west and central African countries jointly, they discovered noteworthy heterogeneities inside the Central African franc (CFAF) zone, and some fascinating likenesses between the central African and WAMZ countries.

Diaz-Bonilla et al (2000) utilized different techniques for cluster analysis (consisting of an approach based on fuzzy sets). The purpose of their study was to group 167 countries by using five indicators of food security such as; food production per capita, the ratio of total exports to food imports, calories per capita, protein per capita, and the share of the non-agricultural population share. This investigation recognized 12 well defined clusters described by similarities and contrasts over the different measures. it proposed that the Least Developing Countries (LDC) includes large number of food insecure countries. Though some other countries which were not categorized as LDCs, were also food insecure countries. however that there likewise were food unreliable nations that were not LDCs. Net Food Importing Developing countries (NFIDCs) were less precise as a pointer of food powerlessness, with in excess of 33% of those countries not falling under any of the food insecure groups.

On the other hand, some research scholars have preferred to use multidimensional scaling analysis as a method to group countries. Dickes et al (2011) introduced a conceptually based, multidimensional and comparable measurement of social cohesion applicable in 47 European countries utilizing the latest miniaturized scale level information of European Value Study (EVS) from 2008. They directed their examination in four stages. In the initial stage, they made a lot of quantifiable moderate indicators that relate to social cohesion dimensions proposed by the theory. In the subsequent stage, they checked whether these indicators observationally verify the multidimensional structure of the idea suggested by the theory. In the third stage, evaluated whether the acquired moderate indicators of social cohesion form the same constructs across countries and whether they can yield a cross country equivalent measure of social cohesion. In the fourth step, a composite score of all elements of social union were determined for each of the 47 countries to exhibit appropriateness of this estimation in similar research.

Moreover, some research scholars have preferred to used Cluster analysis and MDS analysis to group and define similarity and/ or dissimilarity between countries. Yenilmez and Girginer (2016) aimed to compare Turkey and EU countries' position regarding women in the labour force indicators, by identifying the similarities and differences between them. They analysed the data of variables specified for the women in the labour forces by using compound methods of Multidimensional scaling analysis (MDSA) and cluster analysis (CA). As indicated by their MDSA, the countries structured three dissimilar groups in two-dimensional space. The groups shaped by the CA were compatible with the groups shaped by the MDSA. When they made a comparison between Turkey and EU member countries, they found that Turkey had exceptionally low values, especially the ratio of working women, the proportion of jobless females -who were elementary or secondary school graduates- and the proportion of ladies who were senior secondary school graduates.

Girginer (2013) investigated the status of Turkey and EU member countries concerning healthcare indicators by determining the similarities and/or dissimilarity between them. She applied the Multidimensional Scaling Analysis (MDSA) and Non-hierarchical Cluster Analysis (NHCA) to data obtained from the 2010 World Health Report. She utilized the data of seven healthcare indicators for Turkey and the 27 EU countries members. Her MDSA revealed a three unique countries' classification in two-dimensional space. Turkey was located with Estonia, Hungary, Lithuania, Poland, Latvia, Slovakia, Bulgaria and Romania in one group. One the other hand, it was dissimilar to Luxembourg, France, Sweden, Austria and Germany and was much similar to Romania and Bulgaria with respect to the analysed health parameters. According to NHCA results and by utilizing the same healthcare indicators, a four country clusters were classified. Turkey was located with Estonia, Hungary, Lithuania, Bulgaria, Latvia, Poland and Romania in one cluster. Countries in the same clusters /groups were similar to one another for both techniques used by the researcher.

Akkucuk (2011) investigated the relative positioning of world economies using competitiveness data released by the World Economic Forum. He used two well known multivariate techniques, Cluster Analysis and Multidimensional Scaling. By using cluster analysis, he compared different solutions with varying number of clusters. He selected the five cluster solution and studied the correspondence of this solution to the five groups established based on GDP of the countries. The results showed that the five group cluster constructed using the 12 variables of the Global Competitiveness Ranking computations correspond moderately to the five groups based on GDP and export structure of the countries, but there were some differences. By using the same twelve variables, he provided a two-dimensional visualization of the countries using the Multidimensional Scaling (MDS) technique. The cluster structure superimposed on the same map of the countries provided a better means of seeing how the clusters are positioned with respect to one another.

2.3. RESEARCH OBJECTIVE

The main objective of this chapter is to group Turkey and sixteen European Union countries according to asphalt pavement applications in those countries. In the scope of main objective of this chapter, there are sub objectives can be summarized as follows:

- Grouping Turkey and the European Union countries according to different variables combinations contain (all asphalt variables with different economic indicators) by using cluster analysis.
- Grouping Turkey and the European Union countries according to different variables combinations contain (all asphalt variables with different economic indicators) by using Multidimensional Scaling analysis (MDS).

- Comparing the analysis results of two methods used and presenting results.

by using two methods of clustering which are cluster analysis and MDS analysis.

2.4. METHODOLOGY

To achieve the objectives of this chapter, we considered two methods of clustering which are cluster analysis and MDS analysis. According to data availability, data of Turkey and only 16 European countries had been obtained. We concentrated on 2016 data set in our analysis. At first, we used these data to perform k-mean cluster analysis. then, we used it to conduct MDS analysis. after that, we made a comparison between the results of using each one of those methods. In section 4.1 and 4.2, we discussed the two analysis methods of cluster MDS.

2.4.1. Cluster analysis

Cluster analysis is a statistical method that permits the classification of homogeneous characteristics for different entities to be in one group. Thereby, the selection process for each variable suggested for clustering is considered crucial, because using different variables combinations might give different result in each trail (Brauksa, 2013). Here, we can differentiate between two major types of clustering methods which are; Hierarchical clustering and Non-hierarchical clustering.

The major difference between hierarchical clustering and non-hierarchical clustering is that the non-hierarchical clustering method (e.g. k-means clustering) allows for determining the number of clusters that a researcher seek to study. This situation is not applicable for hierarchical clustering, where the number of groups can not be determined in advance. To achieve the objectives of this chapter, we preferred to use Non-hierarchical clustering method of k-means.

k-means clustering algorithm can be discussed through steps given by Li and Wu (2012), they describer k-means clustering algorithm as follows:

Given N samples of pattern $\{x_1, x_2, \dots, x_N\}$, which are subject to classifying. They need to be classified to K clusters.

1) Select any one among $\{x_1, x_2, \dots, x_N\}$ to act as the role of first cluster focal point z_1, e.g., they chose $z_1 = x_1$

2) Select another point which is as much as possible far apart to z_1 to be the focal point of the second cluster and calculate the distance between each sample and z_1:

$$\|x_i - z_1\|, \quad i = 1,2, \dots\ N \qquad 2.1$$

If:

$$\|x_i - z_1\| = \max\{\|x_i - z_1\|, \quad i = 1,2, \dots\ N\ \}, \quad j = 1,2, \dots N$$

Then select x_j to be the focal point of the second cluster, and $z_2 = x_j$.

3) Calculate the distance between each sample among $\{x_1, x_2, \dots, x_N\}$ and $\{z_1, z_2\}$ one by one.

$$d_{i1} = \|x_i - z_1\|, \quad i = 1,2, \dots N \qquad 2.2$$

$$d_{i2} = \|x_i - z_2\|, \quad i = 1,2, \dots N \qquad 2.3$$

Select the minimum of the outcomes:

$$\min(d_{i1}, d_{i2}), \quad i = 1,2, \dots N$$

Collect the minimums of all samples of pattern and $\{z_1, z_2\}$. Select the maximum among the minimums to be the third cluster focal point z_3.

If:

$$\min(d_{i1}, d_{i2}) = max\{\min(d_{i1}, d_{i2}), \quad i = 1,2, \dots N\} \qquad 2.4$$

Then:

$$z_3 = x_j \qquad 2.5$$

4) Assume that they have got r $(r < k)$ cluster focal points $\{z_i, \quad i = 1,2, \dots r\}$, they need to determine the r+1th cluster focal point, namely if:

$$\min(d_{j1}, d_{j2}, \dots, d_{jr}) = \max\{\min(d_{j1}, d_{j2}, \dots, d_{jr}), i = 1,2, \dots N\} \ j = 1,2, .. r$$

Then:

$$z_{r+1} = x_j.$$

5) Repeat, till r+1 = K.

6) Now they have chosen K initial cluster focal point $z_1(1),\ z_2(1), z_k(1)$. the numbers in parenthesis are serial numbers used in iterative operations to seek cluster points.

7) According to the rule of minimizing distance, allocate $\{x_1, x_2, \dots, x_N\}$ to one of the K clusters, namely, if:

$$\|x - z_j(t)\| = \min\{\|x - z_i(t)\|, \quad i = 1,2, \dots K\}, \quad j = 1,2, \dots, K \qquad 2.6$$

Then:

$$x \in s_j(t).$$

The symbol t in the formula refers to the serial number of iterative operations, s_j stands for the j th cluster, and the cluster focal point denoted by x_j.

8) Calculate the new vector values of each cluster focal point:

$z_j(t + 1), \quad j = 1,2, \dots, K.$

Calculate the mean vectors of samples of each cluster:

$$z_j(t + 1) = \frac{1}{N_j} \sum_{x \in s_j(t)} x\,, \quad j = 1,2, \dots, K \qquad 2.7$$

The symbol N_j in the formula above refers to the number of samples of the j th cluster s_j. Calculate the mean vectors of samples of the K clusters respectively. Making mean vectors be new clusters can minimize cluster criterion function J_j.

$$J_j = \sum_{x \in s_j(t)} \left\| x - z_j(t+1) \right\|^2, \quad j = 1,2,\dots,K \qquad 2.8$$

9) If: $z_j(t+1) \neq z_j(t) \quad j = 1,2,\dots,K$, then return to 7), classify samples of pattern one by one again, and repeat iterative operations. If $z_j(t+1) = z_j(t) \quad j = 1,2,\dots,K$, then the convergence of the algorithm is finished.

2.4.2. Multidimensional scaling analysis

Multidimensional scaling (MDS) is a method that allows for analysts to acquire quantitative assessments of similarity among clusters or groups. The MDS is utilized to decrease the complication of data collection (Hount et all,2013). The term multidimensional scaling (MDS) was first presented by Torgerson (1951, 1952, 1958) as a technique that can identifying the similarity among different objects. From that time until now, MDS has come to be related with a several geometric models characterizing the idea of spatial portrayal and assorted strategies for fitting those models to data (Weinberg, 1991).

In MDS analysis proximities are the data utilized to perform the analysis. These proximities demonstrate the general comparability or similarity of the objects in the data. MDS will search for a spatial design of the objects with the goal that the distance or farness between the objects coordinate their proximities as intently as could reasonably be expected. The data can be organized in a matrix called the proximities matrix.

At this point, it is worthwhile to present the classical MDS algorithm. The classical MDS algorithm depends on the fact that the coordinate matrix (X) can be derived by eigenvalue decomposition from the scalar product matrix ($B = XX'$). The problem of constructing (B) from the proximity matrix (P) is solved by multiplying the squared proximities with the matrix ($J = I - n^{-1}11'$). This procedure is called double centering. The following steps summarize the algorithm of classical MDS (Wickelmaier, 2003):

1) Establish the matrix of squared proximities ($P^{(2)} = [p^2]$.

2) Apply the double centering: ($B = -\frac{1}{2}JP^{(2)}J$) using the matrix ($J = I - n^{-1}11'$). Where n refers to the number of objects.

3) Extract the m largest positive eigenvalues $\lambda_1 \dots \lambda_m$ of (B) and the corresponding m eigenvectors $e_1 \dots e_m$.

4) A m-dimensional spatial configuration of the n objects is derived from the coordinate matrix ($X = E_m\Lambda_m^{1/2}$), where E_m is the matrix of m eigenvectors and Λ_m is the diagonal matrix of m eigenvalues of (B), respectively.

2.5. COUNTRIES' GROUPING IN TERMS OF ASPHALT PAVEMENT APPLICATION

In this section, we considered two methods for countries' grouping. We used cluster analysis and Multidimensional scaling analysis to choose the best variables combination and to choose from two methods the one that serves our research objective perfectly. In another word, we used asphalt variables along with other economic indicators to choose the best variables combination. Then, to decide which countries grouping is the best to achieve the main objective of this research.

Thus, in upcoming sections we aimed to group countries according to different variables combinations at first by using K-mean cluster analysis, then by using MDS analysis. Table 2.1 shows the variables used in the two analyses, their symbols and source of data. whereas, Table 2.2 shows the data for each variable presented in Table 2.1.

Table 2.1: Variables used in countries' grouping

Variables	Symbols	Source of Data
Economic Indicators:		
• population density (person per sq.km)	PD	Eurostat and world bank database
• surface area (sq.km)	SA	world bank database
• total population	TP	world bank database
• GDP per capita (us$)	GDP	world bank database
• GNI per capita	GNI	world bank database
Asphalt variables:		
• Number of companies in asphalt industry (production and laying)	X1	EAPA
• Total of bitumen consumption (in million tonnes)	X2	EAPA
• Total production of asphalt (in million tonnes)	Y1	EAPA
• Total length of motorways and main roads (km)	Y2	Eurostat and Statista database

Table 2.2: Data of all variables used in countries grouping

	Asphalt Variables				**Economic Indicators**				
Countries	**x1**	**x2**	**y1**	**y2**	**PD**	**SA**	**TP**	**GDP**	**GNI**
1. Austria	66	0.38	7.4	12682	106	83879.00391	8736668	36300.95936	54130
2. Belgium	18	0.20	5.1	14992	373.7	30530	11331422	34322.75743	42640
3. Croatia	52	0.11	2.2	8068	74.6	56590	4174349	80924.69467	12360
4. Czech rep.	29	0.34	6.7	1228468	136.8	78870	10566332	418139.237	17630
5. Denmark	6	0.19	3.8	3853	136.4	42920	5728010	341213.9644	56990
6. Finland	10	0.27	5.9	13465	18.1	338450	5495303	34719.46861	45040
7. France	30	2.50	33.6	11612	105.3	549086.9922	66859768	31688.46768	38780
8. Germany	150	1.70	41.0	51064	233.1	357580	82348669	34673.93505	44020
9. Great Britain	19	1.295	22.0	52874.33	270.6	243610	65595565	27207.24907	42370
10. Hungary	34	0.14	2.8	31986	107.6	93030	9814023	3118580.364	12500
11. Italy	400*	1.16	23.1	6943	205.4	301340	60627498	25912.00778	31700
12. Netherlands	17	0.29	8.2	5355	498.1	41540	17030314	39464.48701	46610
13. Norway	13	0.38	7.2	11087	16.9	625217.1094	5234519	545890.8337	82010
14. Slovakia	2	0.10	1.9	4353	102.5	49030	5430798	14553.55695	17010
15. Slovenia	13	0.08	1.6	6225.2	111.5	20675	2065042	18468.69996	21700
16. Spain	125	0.60	13.1	30390	92.5	505935	46484062	23788.15345	27580
17. Turkey	312	2.93	40.4	33648	103.4	785350	79512426	19825.39182	11230

*estimated value according to EAPA

By using all asphalt variables and some of economic indicators (Table 2.1), we analysed the data of different variables combinations. In the first variables combination, we used only asphalt variables. Then, in each other variables combinations we used all asphalt variables with different economic indicators.

2.5.1. Cluster Analysis

This section presents the findings of using K-mean clustering for different variables combination. For the first variables combination we used only asphalt variables data without any economic indicator. For other variables combinations, we used all asphalt variables along with different economic indicators in each trial.

1. The First Variables Combination of (x1, x2, y1,y2)

In this variable combination, we used asphalt variables (**x1, x2, y1, y2**) to cluster Turkey and European Union countries. The results of using this variables combination are presented in Table 2.3.

Table 2.3: Cluster Analysis Results of Using The First Variables Combination of (x1, x2, y1, y2)

	First iteration			Third & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	21247.55	**1. Austria**	1,215,823.74	6,000.23	2
2. Belgium	2360.48	18988.03	**2. Belgium**	1,213,488.74	3,740.71	2
3. Croatia	4633.47	25881.02	**3. Croatia**	1,220,427.73	10,633.70	2
4. Czech Rep	1215824	1195139	**4. Czech Rep**	**0**	**1,209,863.28**	**1**
5. Denmark	8892.79	30140.34	**5. Denmark**	1,224,641.05	14,893.02	2
6. Finland	840.61	20522.16	**6. Finland**	1,215,022.87	5,274.84	2
7. France	1134.32	22325.23	**7. France**	1,216,886.06	7,121.16	2
8. Germany	38500.92	17579.83	**8. Germany**	1,177,560.66	32,500.69	2
9. Great Britain	40254.85	19539.37	**9. Great Britain**	1,175,619.93	34,280.99	2

10. Hungary	19340.84	1980.39	**10. Hungary**	1,196,491.10	13,380.38	2
11. Italy	6089.48	26812.07	**11. Italy**	1,221,913.22	12,049.94	2
12. Netherlands	7376.89	28622.84	**12. Netherlands**	1,223,126.55	13,375.52	2
13. Norway	1648.2	22895.75	**13. Norway**	1,217,397.54	7,648.43	2
14. Slovakia	8398.78	29646.33	**14. Slovakia**	1,224,147.04	14,399.01	2
15. Slovenia	6515.9	27763.45	**15. Slovenia**	1,222,264.16	12,516.13	2
16. Spain	17772.92	3474.63	**16. Spain**	1,198,180.66	11,774.24	2
17. Turkey	21247.55	0	**17. Turkey**	1,195,139.29	15,247.32	2

As shown in Table 2.3 the cluster analysis ended in the third iteration and gave us the following result of countries' grouping:

Group 1: Czech Republic

Group 2: all other countries

2. The Second variables combination of (x1, x2, y1, y2 & SA)

According to this variables combination, we used all asphalt variables data of (**x1, x2, y1, y2**) along with only one economic indicator data which is Surface Area (**SA**). The results of using this variables combination is presented in Table 2.4.

Table 2.4: Cluster Analysis Results of Using The Second Variables Combination of (x1, x2, y1, y2 & SA)

	First iteration			**Fourth & last iteration**		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	722718.5	**1. Austria**	134,056.95	420,848.35	1
2. Belgium	55709.48	773808	**2. Belgium**	165,439.84	471,937.83	1
3. Croatia	31922.47	754641	**3. Croatia**	146,325.63	452,770.82	1

4. Czech Rep	1220833	1901619	**4. Czech Rep**	1,096,388.90	1,621,842.52	1
5. Denmark	49851.79	772570.3	**5. Denmark**	164,202.15	470,700.14	1
6. Finland	255411.6	467422.2	**6. Finland**	**387,819.17**	**165,551.96**	**2**
7. France	466342.3	258588.2	**7. France**	**600,327.26**	**65,497.67**	**2**
8. Germany	312201.9	445349.8	**8. Germany**	**369,494.87**	**165,610.45**	**2**
9. Great Britain	199985.8	561279.4	**9. Great Britain**	253,577.34	281,502.60	1
10. Hungary	28491.84	694300.4	**10. Hungary**	123,874.20	411,199.62	1
11. Italy	223550.5	510822.1	**11. Italy**	**357,607.43**	**209,278.73**	**2**
12. Netherlands	49715.89	772432.8	**12. Netherlands**	164,068.71	470,562.64	1
13. Norway	542986.3	183028.6	**13. Norway**	**676,962.06**	**142,175.78**	**2**
14. Slovakia	43247.78	765966.3	**14. Slovakia**	157,598.14	464,096.13	1
15. Slovenia	69719.9	792438.5	**15. Slovenia**	184,070.26	490,568.25	1
16. Spain	439828.9	282889.6	**16. Spain**	**538,469.87**	**19,049.98**	**2**
17. Turkey	722718.5	0	**17. Turkey**	**814,843.50**	**301,870.20**	**2**

From Table 2.4, it can be noticed that the cluster analysis ended after the fourth iteration which gave us the following result:

Group 1: Austria, Belgium, Croatia, Czech Republic, Denmark, Great Britain, Hungary, Netherlands, Slovakia, Slovenia.

Group 2: ***Finland, France, Germany, Italy, Norway, Spain, Turkey***

3. The Third Variables Combination of (x1, x2, y1, y2 & TP)

In this variables combination we also used all asphalt variables data (x1, x2, y1, y2) along with only one economic indicator which is Total Population (TP). The results of using this combination is shown in Table 2.5.

Table 2.5: Cluster Analysis Results of Using The Third Variables Combination of (x1, x2, y1, y2 & TP)

	First iteration			Second & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	70797006	**1. Austria**	1,063,463.32	58,186,532.67	1
2. Belgium	2597114	68199992	**2. Belgium**	3,655,868.16	55,589,519.15	1
3. Croatia	4566952	75363958	**3. Croatia**	3,721,915.37	62,753,485.14	1
4. Czech Rep	3045488	70141233	**4. Czech Rep**	3,890,506.09	57,535,879.30	1
5. Denmark	3017551	73814556	**5. Denmark**	2,172,456.96	61,204,083.46	1
6. Finland	3242206	74037645	**6. Finland**	2,395,548.07	61,427,172.28	1
7. France	58124234	12674983	**7. France**	**59,187,625.64**	**64,521.42**	**2**
8. Germany	73650502	2853823	**8. Germany**	**74,637,201.24**	**15,464,014.58**	**2**
9. Great Britain	56899152	13936400	**9. Great Britain**	**57,882,145.78**	**1,331,046.38**	**2**
10. Hungary	1096696	69700383	**10. Hungary**	2,121,481.65	57,091,705.40	1
11. Italy	51896919	18911740	**11. Italy**	**52,960,382.80**	**6,301,545.86**	**2**
12. Netherlands	8301023	62510735	**12. Netherlands**	9,364,401.30	49,900,261.96	1
13. Norway	3503797	74300803	**13. Norway**	2,658,708.48	61,690,329.87	1
14. Slovakia	3314269	74111274	**14. Slovakia**	2,469,174.95	61,500,801.45	1
15. Slovenia	6678142	77475147	**15. Slovenia**	5,833,048.07	64,864,674.57	1
16. Spain	37765167	33031839	**16. Spain**	**38,793,214.24**	**20,421,365.75**	**2**
17. Turkey	70797006	0	**17. Turkey**	**71,818,536.87**	**12,610,472.88**	**2**

As it is shown in Table 2.5, the cluster analysis ended after the second iteration which had made the countries' grouping be as following:

Group 1: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Netherlands, Norway, Slovakia, Slovenia.

Group2*: France, Germany, Great Britain, Italy, Spain, Turkey.*

4. The fourth variables combination of (x1, x2, y1, y2 & GDP)

According to this variables combination, we also used all asphalt variables data along with only one economic indicator which is Gross Domestic Product per capita (GDP). Table 2.6 shows the results of using this variables combination.

Table 2.6: Cluster Analysis Results of Using The Fourth Variables Combination of (x1, x2, y1, y2 & GDP)

	First iteration			Fourth & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	37723.12	**1. Austria**	152,422.71	3,101,620.24	1
2. Belgium	4338.682	33485.4	**2. Belgium**	152,141.39	3,101,269.97	1
3. Croatia	49257.21	86980.32	**3. Croatia**	112,432.44	3,061,592.30	1
4. Czech Rep	1597662	1593453	**4. Czech Rep**	1,445,278.97	3,896,932.23	1
5. Denmark	313805.8	351528.9	**5. Denmark**	322,943.69	2,805,528.45	1
6. Finland	2422.101	35416.24	**6. Finland**	153,278.81	3,102,409.13	1
7. France	5746.812	34188.31	**7. France**	158,155.61	3,107,303.06	1
8. Germany	40127.94	32428.37	**8. Germany**	115,746.99	3,103,140.19	1
9. Great Britain	49348.56	26921.22	**9. Great Britain**	121,372.70	3,112,296.80	1
10. Hungary	3101620	3100735	**10. Hungary**	**3,072,150.14**	**0**	**2**
11. Italy	16478.43	32898.69	**11. Italy**	168,861.48	3,118,098.68	1
12. Netherlands	10540.42	48261.94	**12. Netherlands**	156,634.47	3,105,769.43	1
13. Norway	511238.1	548961.2	**13. Norway**	520,375.97	2,593,614.17	1
14. Slovakia	30146.18	34918.16	**14. Slovakia**	182,568.89	3,131,692.75	1
15. Slovenia	24348.16	29120.14	**15. Slovenia**	176,770.86	3,125,894.72	1
16. Spain	30285.73	7437.392	**16. Spain**	147,254.84	3,096,489.97	1
17. Turkey	37723.12	0	**17. Turkey**	148,174.17	3,100,735.36	1

as shown in Table 2.6, the cluster analysis ended after the fourth iteration and resulted into grouping countries into the following:

Group 1: all countries except Hungary

Group 2: Hungary

5. The Fifth Variables Combination of (x1, x2, y1, y2 & GNI)

In this variables combination, the only economic indicator data we used is Gross National Income per capita (GNI) along with all asphalt variables data of (x1, x2, y1, y2). Table 2.7 shows the results of using this variables combination.

Table 2.7: Cluster Analysis Results of Using The Fifth Variables Combination of (x1, x2, y1, y2 & GNI)

	First iteration			Third & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	64147.55	**1. Austria**	23,463.35	1,252,323.74	1
2. Belgium	13850.48	50398.03	**2. Belgium**	9,713.83	1,238,498.74	1
3. Croatia	46403.47	27011.02	**3. Croatia**	34,940.57	1,225,697.73	1
4. Czech Rep	1252324	1201539	**4. Czech Rep**	**1,228,900.15**	**0**	**2**
5. Denmark	11752.79	75900.34	**5. Denmark**	35,216.14	1,264,001.05	1
6. Finland	9930.61	54332.16	**6. Finland**	13,647.96	1,242,432.87	1
7. France	16484.32	49875.23	**7. France**	9,234.28	1,238,036.06	1
8. Germany	48610.92	50369.83	**8. Germany**	39,853.82	1,203,950.66	1
9. Great Britain	52014.85	50679.37	**9. Great Britain**	39,984.12	1,200,359.93	1
10. Hungary	60970.84	3250.39	**10. Hungary**	37,547.25	1,201,621.10	1
11. Italy	28519.48	47282.07	**11. Italy**	17,016.82	1,235,983.22	1
12. Netherlands	14896.89	64002.84	**12. Netherlands**	23,318.64	1,252,106.55	1
13. Norway	29528.2	93675.75	**13. Norway**	52,991.55	1,281,777.54	1
14. Slovakia	45518.78	35426.33	**14. Slovakia**	34,055.88	1,224,767.04	1
15. Slovenia	38945.9	38233.45	**15. Slovenia**	27,483.00	1,226,334.16	1
16. Spain	44322.92	19824.63	**16. Spain**	20,861.12	1,208,130.66	1
17. Turkey	64147.55	0	**17. Turkey**	40,684.20	1,201,539.29	1

From Table 2.7, it can be noticed that the cluster analysis ended after the third iteration which made the grouping of countries be as following:

Group 1: all countries except Czech Republic.

Group 2: Czech Republic

6. The sixth variables combination of (x1, x2, y1, y2 & GDP, GNI)

In the sixth variables combination, we used two economic indicators data of (GDP, GNI) along with all asphalt variables data of (x1, x2, y1, y2). The clustering results of using this variables combination are shown in Table 2.8.

Table 2.8: Cluster Analysis Results of Using The Sixth Variables Combination of (x1, x2, y1, y2 & GDP, GNI)

	First iteration			Fourth & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	80623.12	**1. Austria**	169,565.21	3,143,250.24	1
2. Belgium	15828.68	64895.4	**2. Belgium**	157,793.89	3,131,409.97	1
3. Croatia	91027.21	88110.32	**3. Croatia**	137,059.94	3,061,732.30	1
4. Czech republic	1634162	1599853	**4. Czech republic**	1,464,636.47	3,902,062.23	1
5. Denmark	316665.8	397288.9	**5. Denmark**	342,946.19	2,850,018.45	1
6. Finland	11512.1	69226.24	**6. Finland**	161,331.31	3,134,949.13	1
7. France	21096.81	61738.31	**7. France**	159,948.11	3,133,583.06	1
8. Germany	50237.94	65218.37	**8. Germany**	122,779.49	3,134,660.19	1
9. Great Britain	61108.56	58061.22	**9. Great Britain**	126,755.20	3,142,166.80	1
10. Hungary	3143250	3102005	**10. Hungary**	**3,096,637.64**	**0**	**2**
11. Italy	38908.43	53368.69	**11. Italy**	174,148.98	3,137,298.68	1
12. Netherlands	18060.42	83641.94	**12. Netherlands**	166,256.97	3,139,879.43	1
13. Norway	539118.1	619741.2	**13. Norway**	565,398.47	2,663,124.17	1
14. Slovakia	67266.18	40698.16	**14. Slovakia**	202,546.39	3,136,202.75	1
15. Slovenia	56778.16	39590.14	**15. Slovenia**	192,058.36	3,135,094.72	1
16. Spain	56835.73	23787.39	**16. Spain**	156,662.34	3,111,569.97	1
17. Turkey	80623.12	0	**17. Turkey**	173,931.67	3,102,005.36	1

As it is shown in Table 2.8, the cluster analysis ended after the fourth iteration which gave the following grouping result:

Group 1: all countries except Hungary

Group 2: Hungary

7. The Seventh Variables Combination of (x1, x2, y1, y2 & GDP, GNI & PD)

According to this variable’s combination, we clustered countries by using all asphalt data of (x1, x2, y1, y2) along with three economic indicators data of (GDP, GNI, PD). The results of using this variables combination data in cluster analysis are shown in Table 2.9.

Table 2.9: Cluster Analysis Results of Using The Seventh Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD)

	First iteration			Second & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	80625.72	**1. Austria**	169,620.76	3,143,251.84	1
2. Belgium	16096.38	65165.7	**2. Belgium**	158,006.03	3,131,676.07	1
3. Croatia	91058.61	88139.12	**3. Croatia**	137,146.90	3,061,765.30	1
4. Czech Rep	1634193	1599887	**4. Czech Rep**	1,464,661.22	3,902,091.43	1
5. Denmark	316696.2	397321.9	**5. Denmark**	342,971.34	2,850,047.25	1
6. Finland	11600	69311.54	**6. Finland**	161,474.76	3,135,038.63	1
7. France	21097.51	61740.21	**7. France**	160,004.37	3,133,585.36	1
8. Germany	50365.04	65348.07	**8. Germany**	122,851.04	3,134,785.69	1
9. Great Britain	61273.16	58228.42	**9. Great Britain**	126,864.24	3,142,329.80	1
10. Hungary	3143252	3102010	**10. Hungary**	**3,096,691.59**	**0**	**2**
11. Italy	39007.83	53470.69	**11. Italy**	174,192.83	3,137,396.48	1
12. Netherlands	18452.52	84036.64	**12. Netherlands**	166,593.51	3,140,269.93	1
13. Norway	539207.2	619827.7	**13. Norway**	565,543.12	2,663,214.87	1
14. Slovakia	67269.68	40699.06	**14. Slovakia**	202,605.44	3,136,207.85	1
15. Slovenia	56783.66	39598.24	**15. Slovenia**	192,108.42	3,135,098.62	1
16. Spain	56849.23	23798.29	**16. Spain**	156,731.40	3,111,585.07	1
17. Turkey	80625.72	0	**17. Turkey**	173,989.82	3,102,009.56	1

According to Table 2.9, the cluster analysis ended after the second iteration which gave the following result of grouping:

Group 1: all countries except Hungary

Group 2: Hungary

8. The Eighth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA)

According to this variables combination, we used all asphalt variables data of (x1, x2, y1, y2) along with four economic indicators data of (GDP, GNI, PD, SA) to cluster countries. The results of countries' clustering are shown in Table 2.10.

Table 2.10: Cluster Analysis Results of Using The Eighth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA)

	First iteration			Second & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	0	782096.7136	**1. Austria**	3,152,402.84	342,654.45	2
2. Belgium	69445.38584	819985.6956	**2. Belgium**	3,194,176.07	384,388.73	2
3. Croatia	118347.6092	816899.1229	**3. Croatia**	3,098,205.30	337,469.59	2
4. Czech Rep	1639201.822	2306366.535	**4. Czech Rep**	3,916,251.43	1,642,703.92	2
5. Denmark	357655.199	1139751.913	**5. Denmark**	2,900,157.25	556,964.04	2
6. Finland	266170.9968	516211.5368	**6. Finland**	3,380,458.63	243,012.07	2
7. France	486305.5	298003.2137	**7. France**	3,589,642.35	452,178.67	2
8. Germany	324066.0404	493118.0732	**8. Germany**	3,399,335.69	223,518.34	2
9. Great Britain	221004.1514	599968.4223	**9. Great Britain**	3,292,909.80	140,166.93	2
10. Hungary	3152402.841	3794329.562	**10. Hungary**	**0**	**3,260,574.29**	**1**
11. Italy	256468.8277	537480.686	**11. Italy**	3,345,706.48	218,620.13	2
12. Netherlands	60791.52156	827846.6352	**12. Netherlands**	3,191,759.93	381,966.21	2
13. Norway	1080545.28	779960.5825	**13. Norway**	3,195,401.98	933,847.54	2
14. Slovakia	102118.6863	777019.0649	**14. Slovakia**	3,180,207.85	410,488.14	2
15. Slovenia	119987.6633	804273.2419	**15. Slovenia**	3,207,453.62	428,346.12	2
16. Spain	478905.222	303213.2916	**16. Spain**	3,524,490.07	405,753.70	2
17. Turkey	782096.7136	0	**17. Turkey**	3,794,329.56	702,427.13	2

As shown in Table 2.10, the cluster analysis ended after the second iteration which made the grouping of countries to be as follows:

Group 1: Hungary

Group 2: all other countries

9. The Ninth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA, TP)

In the last variables combination analysis, we used all asphalt variables data of (x1, x2, y1, y2) along with all economic indicators data of (GDP, GNI, PD, SA, TP). The results from cluster analysis applied for this variables combination are shown in Table 2.11.

Table 2.11: Cluster Analysis Results of Using The Ninth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA, TP)

	First iteration			Fourth & last iteration		
Countries	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Countries**	**Distance to mean of cluster 1**	**Distance to mean of cluster 2**	**Clusters**
1. Austria	3366313.199	3407988.686	**1. Austria**	1,518,795.75	58,590,501.48	1
2. Belgium	5948432.817	5975452.7	**2. Belgium**	4,155,211.64	56,033,511.69	1
3. Croatia	1876574.75	1338823.348	**3. Croatia**	4,167,749.02	63,228,134.75	1
4. Czech Rep	6215198.723	6793761.02	**4. Czech Rep**	3,971,512.99	58,320,131.25	1
5. Denmark	0	670502.2975	**5. Denmark**	2,366,664.99	61,956,753.87	1
6. Finland	856417.9758	411329.4817	**6. Finland**	3,000,201.42	61,565,986.50	1
7. France	61973506.7	61975255.8	**7. France**	**59,999,599.78**	**167,193.77**	**2**
8. Germany	77302319.44	77320581.68	**8. Germany**	**75,259,955.47**	**15,582,547.70**	**2**
9. Great Britain	60446059.55	60446088.42	**9. Great Britain**	**58,396,784.19**	**1,554,470.31**	**2**
10. Hungary	6986170.25	7563432.847	**10. Hungary**	4,878,829.35	60,567,397.68	1
11. Italy	55502073.23	55478171.61	**11. Italy**	**53,534,205.80**	**6,459,577.07**	**2**
12. Netherlands	11617692.68	11662936.02	**12. Netherlands**	9,851,687.45	50,342,480.63	1
13. Norway	1312849.069	1375639.566	**13. Norway**	3,316,332.44	62,426,653.10	1
14. Slovakia	670502.2975	0	**14. Slovakia**	2,984,261.84	61,937,219.98	1
15. Slovenia	4045654.674	3404608.663	**15. Slovenia**	6,367,875.81	65,320,833.96	1
16. Spain	41592612.42	41556155.3	**16. Spain**	**39,577,884.05**	**20,478,654.02**	**2**
17. Turkey	74924167.91	74858647.06	**17. Turkey**	**72,902,923.54**	**12,967,478.00**	**2**

From Table 2.11, it can be noticed that, the cluster analysis ended after the fourth iteration and countries' grouping resulted to be as follows:

Group 1: ***France, Germany, Great Britain, Italy, Spain and Turkey***

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Netherlands, Norway, Slovakia, Slovenia.

2.5.2. Multidimensional Scaling Analysis (MDS)

In this section, we aimed to group Turkey and European Union countries by using multidimensional scaling method of (PROXSCAL) for the same variables combinations used in cluster analysis. Afterwards, a comparison between two methods was conducted to choose the best clusters.

1. The First Variables Combination of (x1, x2, y1, y2)

In this section, we used asphalt variables data of (x1, x2, y1, y2) to group countries by using MDS method. The results of this analysis are shown in Table 2.12 and figure 2.1.

Table 2.12: Stimulus Coordinates of Using The First Variables Combination of (x1, x2, y1, y2)

Countries	Dimensions	
	1	2
1. Austria	**-0.442**	**-0.170**
2. Belgium	**-0.452**	**-0.163**
3. Croatia	**-0.355**	**-0.248**
4. Czech Republic	**-0.398**	**-0.122**
5. Denmark	**-0.387**	**-0.147**
6. Finland	**-0.347**	**-0.130**
7. France	**-0.332**	**-0.097**
8. Germany	**-0.534**	**1.301**
9. Great Britain	**-0.285**	**-0.069**
10. Hungary	**-0.186**	**-0.164**
11. Italy	**-0.274**	**-0.098**
12. Netherlands	**0.053**	**-0.170**
13. Norway	**0.196**	**0.174**
14. Slovakia	**0.858**	**-0.656**
15. Slovenia	**0.801**	**0.141**
16. Spain	**1.339**	**0.266**
17. Turkey	**0.746**	**0.354**
Stress and Fit measures Stress: 0.00720 Tucker’s coefficient of congruence: 0.99639		

Figure 2.1.: Common Space Objects Points for First Variables combination

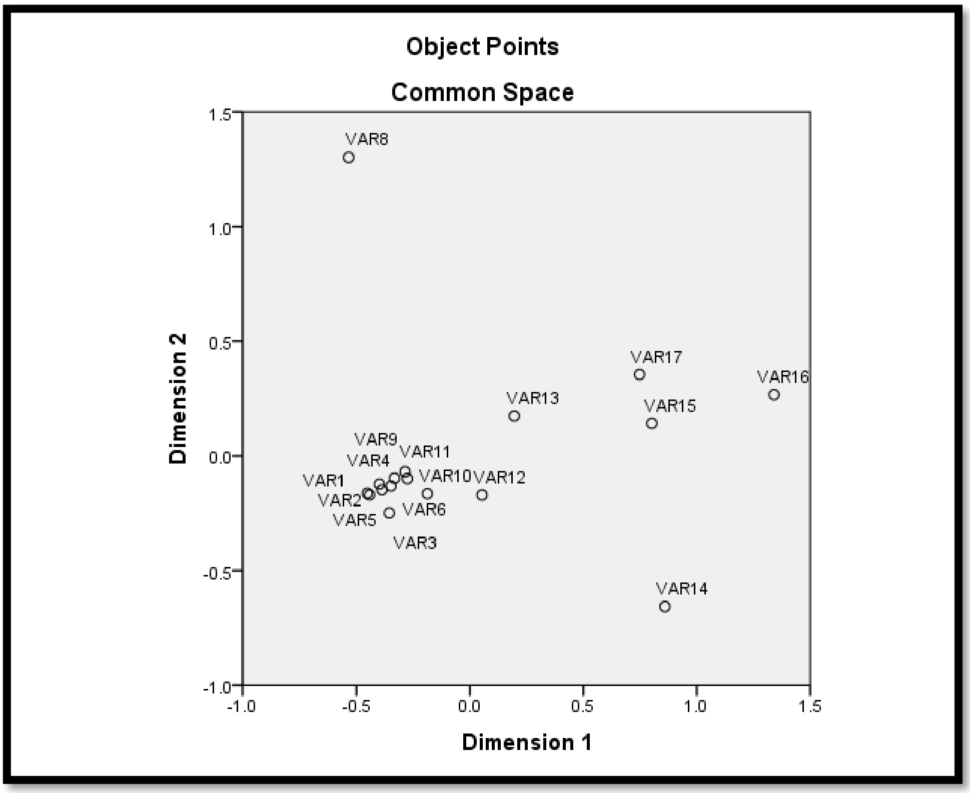


Table 2.12 shows the results of stimulus coordinates, with stress value of (0.00720 <0.025) we can say that the model is perfectly fitted. As shown in Table 2.12, Spain in the first dimension and Germany in the second dimension have the highest positives values and that Germany has its own attributes which differ from other countries in the second dimension. Also, it can be noticed that Slovakia, Slovenia and Turkey are similar to each other in terms of asphalt variables used in this variables combination.

According to Table 2.12 and Figure 2.1, we grouped countries into two groups, as follows:

Group 1: ***Spain, Slovakia, Slovenia, Turkey, Norway and Netherlands***.

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Hungary and Italy.

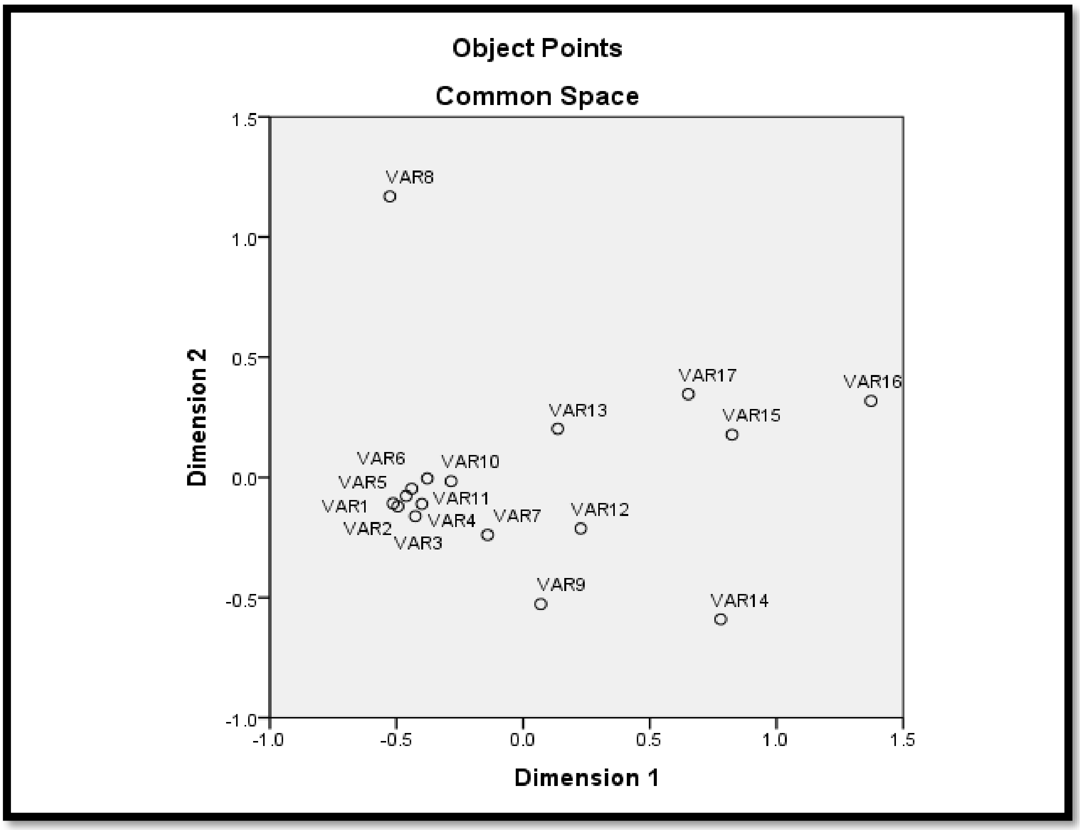
2. The Second variables combination of (x1, x2, y1, y2 & SA)

In analysing this variables combination, we used asphalt variables data of (x1, x2, y1, y2) along with only one economic indicator data of (SA). Table 2.13 and Figure 2.2 show the results of analysing this variables combination by using MDS.

Table 2.13: Stimulus Coordinates of Using The Second Variables Combination of (x1, x2, y1, y2 & SA)

Countries	Dimensions	
	1	2
1. Austria	-0.513	-0.108
2. Belgium	-0.494	-0.120
3. Croatia	-0.425	-0.161
4. Czech Republic	-0.399	-0.110
5. Denmark	-0.461	-0.077
6. Finland	-0.439	-0.046
7. France	-0.140	-0.238
8. Germany	-0.526	1.168
9. Great Britain	0.069	-0.526
10. Hungary	-0.284	-0.015
11. Italy	-0.378	-0.003
12. Netherlands	0.227	-0.212
13. Norway	0.136	0.202
14. Slovakia	0.780	-0.589
15. Slovenia	0.824	0.177
16. Spain	1.373	0.317
17. Turkey	0.651	0.346
Stress and Fit measures Stress: 0.0111 Tucker's coefficient of congruence: 0.994407		

Figure 2.2: Common Space Objects Points for Second Variables combination



As shown in Table 2.13, the stress value of this model was (0.0111<0.025) which indicates that the model is a perfect fit. As shown in Table 2.13, Spain and Germany have the highest positive values. Germany has attributes differ from other countries in the second dimension. Also, it can be said that Turkey, Slovakia and Slovenia are similar in their attributes regarding the five variables used in this variables combination.

According to MDS analysis results showing in Table 2.13 and Figure 2.2, the countries' grouping can be as follows:

Group 1: ***France, Spain, Slovakia, Slovenia, Turkey, Norway, Netherlands and Great Britain.***

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary and Italy.

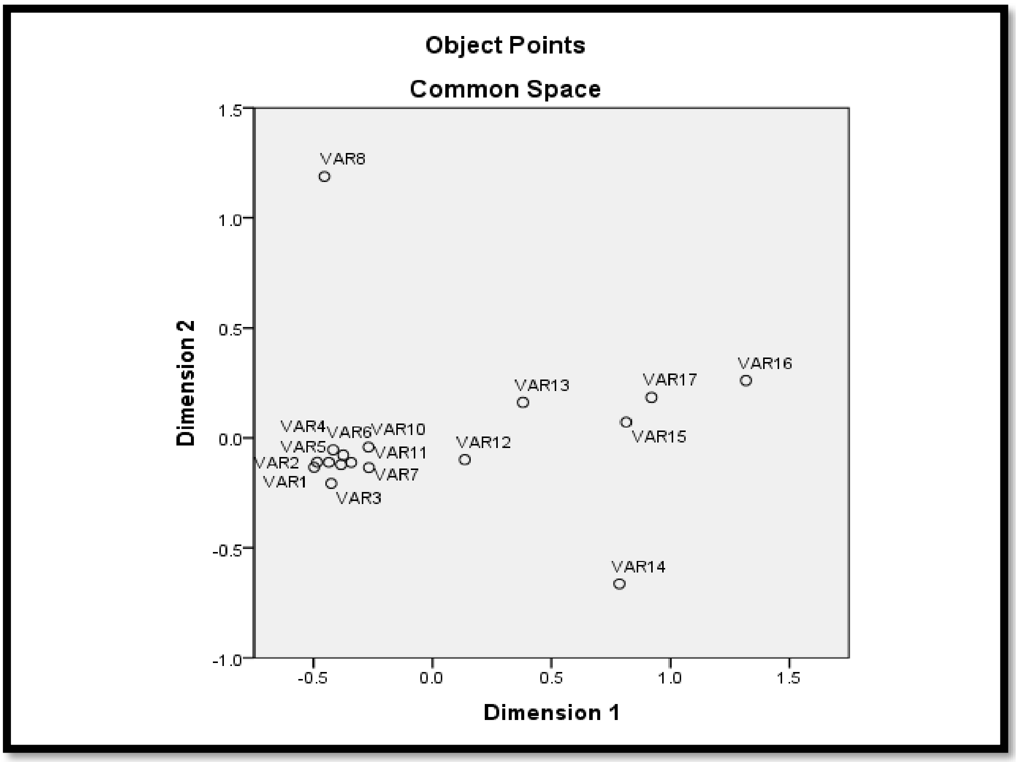
3. The Third Variables Combination of (x1, x2, y1, y2 & TP)

To analyse the third variables combination, we also used only one economic indicator data of (TP) along with data of asphalt variables (x1, x2, y1, y2). The results of MDS analysis of this combination are shown in Table 2.14 and Figure 2.3.

Table 2.14: Stimulus Coordinates of Using The Third Variables Combination of (x1, x2, y1, y2 & TP)

Countries	Dimensions	
	1	2
1. Austria	-0.497	-0.133
2. Belgium	-0.484	-0.110
3. Croatia	-0.425	-0.207
4. Czech Republic	-0.417	-0.054
5. Denmark	-0.435	-0.111
6. Finland	-0.374	-0.078
7. France	-0.384	-0.121
8. Germany	-0.453	1.188
9. Great Britain	-0.341	-0.111
10. Hungary	-0.269	-0.041
11. Italy	-0.267	-0.134
12. Netherlands	0.135	-0.098
13. Norway	0.379	0.161
14. Slovakia	0.785	-0.663
15. Slovenia	0.813	0.071
16. Spain	1.317	0.261
17. Turkey	0.920	0.183
Stress and Fit measures Stress: 0.0071 Tucker's coefficient of congruence: 0.99642		

Figure 2.3: Common Space Objects Points for Third Variables combination



As shown in Table 2.14, The stress value of this model was (0,007) which is below (0,025) indicating that this model is a perfect fit. According to this model, Spain and Germany have the biggest positive values - as same as the previous model. In the first dimension, Spain, Turkey and Slovenia are considered similar to each other. Also that, Germany has its own attributes which differ from any other country in the second dimension.

According to Table 2.14 and Figure 2.3, we can group countries included in this model into two group as follows;

Group 1: ***Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey***.

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Hungary and Italy.

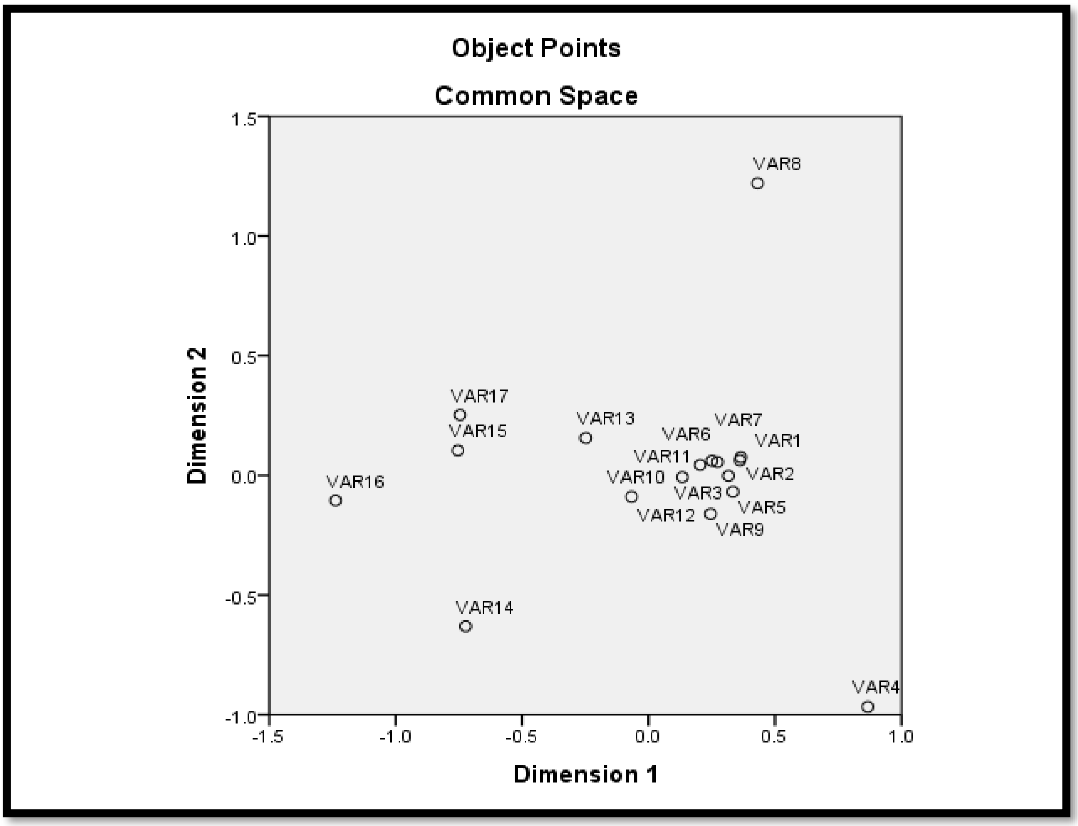
4. **The fourth variables combination of (x1, x2, y1, y2 & GDP)**

To analyse this variables combination, we used the data of only one economic indicator (GDP) along with data of asphalt variables (x1, x2, y1, y2). Table 2.15 and Figure 2.4 show the analysis results of MDS for this variable combination.

Table 2.15: Stimulus Coordinates of Using the Fourth Variables Combination of (x1, x2, y1, y2 & GDP)

Countries	Dimensions	
	1	2
1. Austria	0.361	0.062
2. Belgium	0.364	0.075
3. Croatia	0.315	-0.002
4. Czech Republic	0.866	-0.966
5. Denmark	0.333	-0.068
6. Finland	0.272	0.056
7. France	0.250	0.060
8. Germany	0.430	1.220
9. Great Britain	0.245	-0.160
10. Hungary	0.133	-0.007
11. Italy	0.204	0.043
12. Netherlands	-0.067	-0.089
13. Norway	-0.248	0.155
14. Slovakia	-0.723	-0.630
15. Slovenia	-0.754	0.103
16. Spain	-1.237	-0.105
17. Turkey	-0.745	0.252
Stress and Fit measures Stress: 0.01208 Tucker’s coefficient of congruence: 0.99393		

Figure 2.4: Common Space Objects Points for Fourth Variables combination



As presented in Table 2.15, this model fits perfectly with stress value (0.012<0.025). Germany has the biggest positive value and it has its own attributes which differ from any other country in this model in terms of the five variables used in analysing this combination. Moreover, countries located in the first dimension which are Austria, Belgium, Croatia and Denmark are considered similar to each other.

By considering the analysis results shown in Table 2.15 and Figure 2.4, we can group countries into two group as follows;

Group 1: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Hungary, Netherlands, Great Britain and Italy.

Group 2: ***Norway, Slovakia, Slovenia, Spain and Turkey*.**

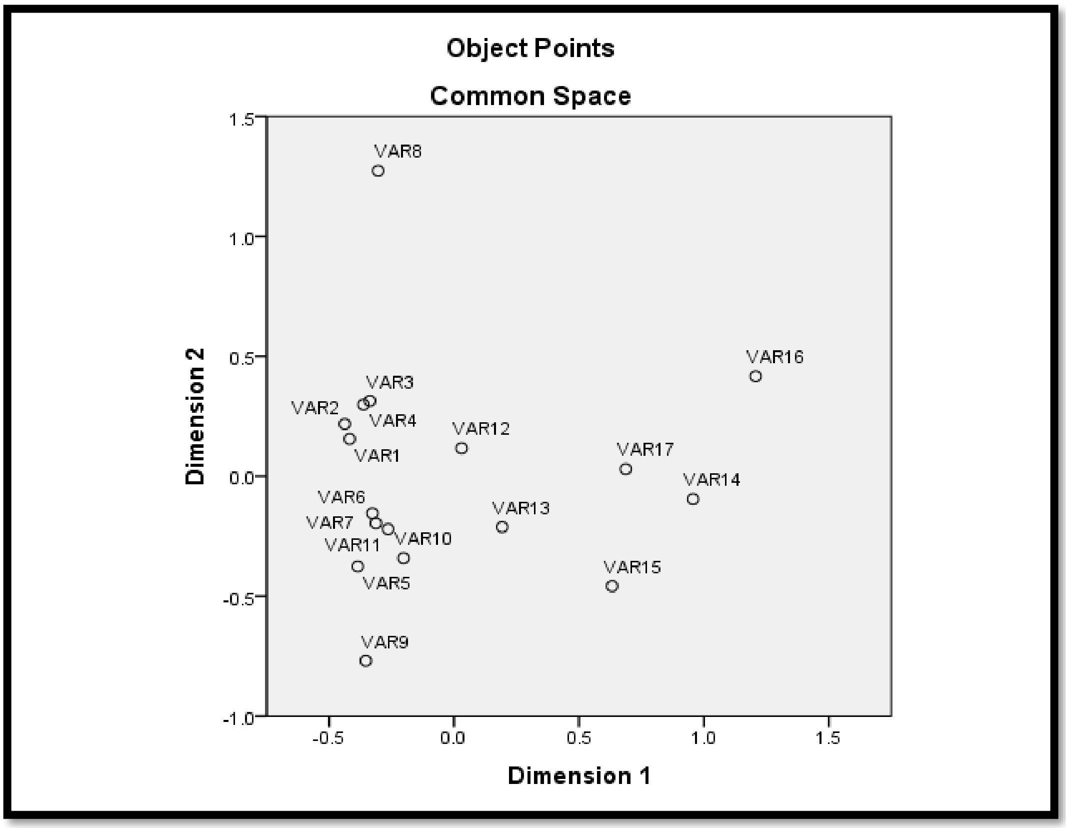
5. The Fifth Variables Combination of (x1, x2, y1, y2 & GNI)

By using this variables combination data of (x1, x2, y1, y2 & GNI), we performed MDS analysis. The analysis results of this analysis are shown in Table 2.16 and Figure 2.5.

Table 2.16: Stimulus Coordinates of Using The Fifth Variables Combination of (x1, x2, y1, y2 & GNI)

Countries	Dimensions	
	1	2
1. Austria	-0.418	0.155
2. Belgium	-0.437	0.217
3. Croatia	-0.337	0.314
4. Czech Republic	-0.362	0.298
5. Denmark	-0.385	-0.376
6. Finland	-0.326	-0.154
7. France	-0.312	-0.195
8. Germany	-0.304	1.273
9. Great Britain	-0.353	-0.769
10. Hungary	-0.202	-0.341
11. Italy	-0.264	-0.220
12. Netherlands	0.030	0.116
13. Norway	0.192	-0.211
14. Slovakia	0.956	-0.095
15. Slovenia	0.632	-0.458
16. Spain	1.206	0.417
17. Turkey	0.687	0.029
Stress and Fit measures Stress: 0.0163 Tucker's coefficient of congruence: 0.99181		

Figure 2.5: Common Space Objects Points for Fifth Variables combination



From Table 2.16, it can be noticed that the stress value of this model was (0.0163<0.025) which indicates that the model is a perfect fit. Also, it can be noticed that Spain and Germany have the highest positive values. Moreover, countries located in the second dimension which are Austria, Netherlands, Croatia and Czech Republic are similar to each other and Germany has its own attributes which made it far away from other countries in the second dimension.

According to Table 2.16 and Figure 2.5, we can group countries into two clusters as follows:

Group 1: ***Norway, Slovakia, Slovenia, Spain and Turkey.***

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Hungary, Italy and Netherlands.

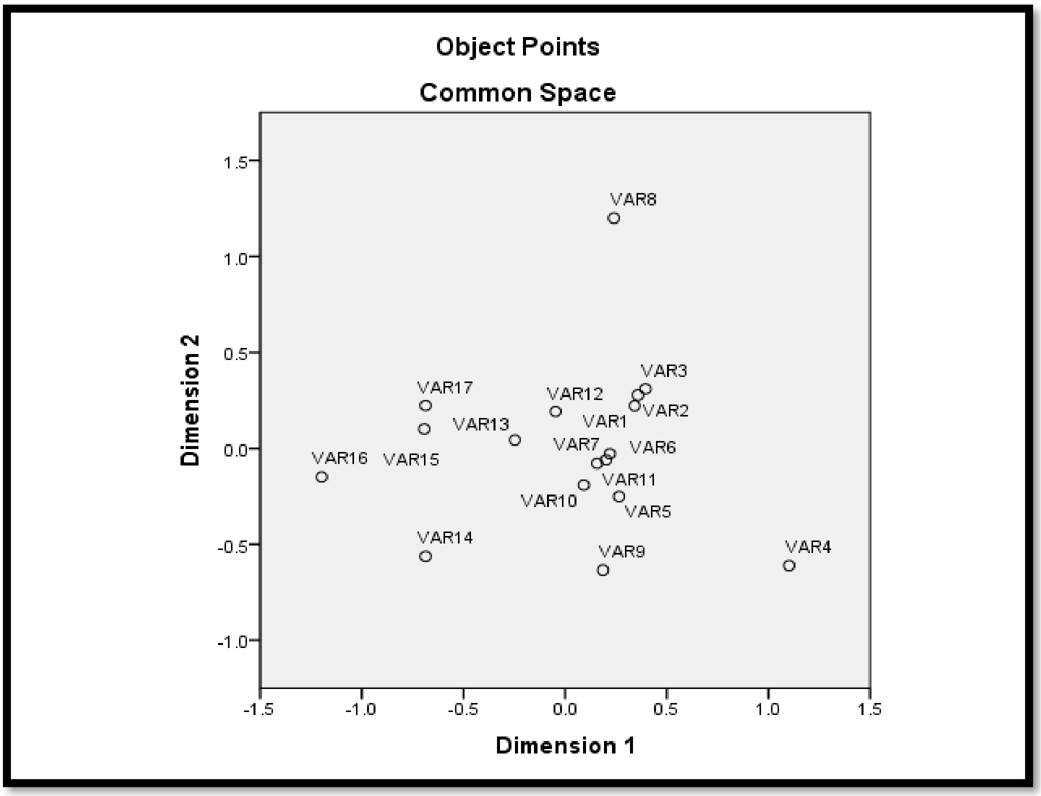
6. The sixth variables combination of (x1, x2, y1, y2 & GDP, GNI)

This variables combination contains two economic indicators (GDP, GNI) and asphalt variables (x1, x2, y1, y2). MDS analysis was performed to group countries by using the data of each variable of this variables combination. Table 2.17 and Figure 2.6 show the results of implementing MDS on this combination.

Table 2.17: Stimulus Coordinates of Using The Sixth Variables Combination of (x1, x2, y1, y2 & GDP, GNI)

Countries	Dimensions	
	1	2
1. Austria	0.341	0.221
2. Belgium	0.358	0.277
3. Croatia	0.394	0.308
4. Czech Republic	1.101	-0.610
5. Denmark	0.265	-0.251
6. Finland	0.219	-0.027
7. France	0.201	-0.060
8. Germany	0.239	1.198
9. Great Britain	0.186	-0.634
10. Hungary	0.091	-0.191
11. Italy	0.157	-0.078
12. Netherlands	-0.047	0.191
13. Norway	-0.247	0.043
14. Slovakia	-0.686	-0.562
15. Slovenia	-0.692	0.101
16. Spain	-1.197	-0.148
17. Turkey	-0.686	0.223
Stress and Fit measures Stress: 0.0248 Tucker’s coefficient of congruence: 0.98750		

Figure 2.6: Common Space Objects Points for Sixth Variables combination



According to Table 2.17, the stress value of this model was (0.0248) which is below (0.025) indicating that this model is a perfect fit. From Table 2.17, it can be noticed that Czech Republic and Germany have the highest positive values. Countries located in the first dimension Austria, Belgium and Croatia are similar to each other. Also that, Slovenia and Netherlands are similar with a distance of (0.090) from each other and they are located in the second dimension. Also, it can be noticed that Spain in the first dimension has the highest negative value which indicates that this country is the most insignificant one to first dimension.

According to MDS analysis results shown in Table 2.17 and Figure 2.6, countries' grouping can be showed as follows:

Group 1: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Hungary, Great Britain and Italy.

Group 2: ***Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey***.

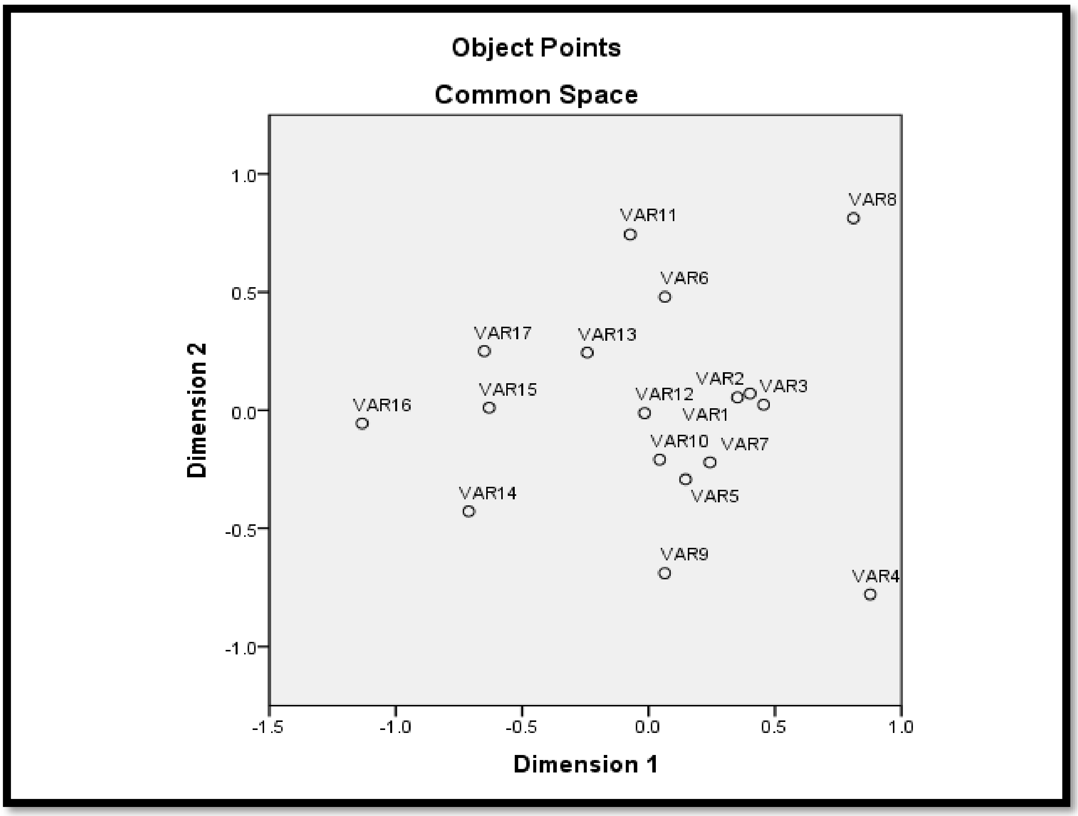
7. The Seventh Variables Combination of (x1, x2, y1, y2 & GDP, GNI & PD)

In MDS analysis, we used the data of this variables combination which contains three economic indicators (GDP, GNI, PD) and asphalt variables (x1, x2, y1, y2). The analysis results of this variables combination are shown in Table 2.18 and Figure 2.7.

Table 2.18: Stimulus Coordinates of Using The Seventh Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD)

Countries	Dimensions	
	1	2
1. Austria	**0.351**	**0.053**
2. Belgium	**0.400**	**0.071**
3. Croatia	**0.454**	**0.023**
4. Czech Republic	**0.876**	**-0.779**
5. Denmark	**0.146**	**-0.293**
6. Finland	**0.064**	**0.479**
7. France	**0.242**	**-0.220**
8. Germany	**0.809**	**0.812**
9. Great Britain	**0.064**	**-0.689**
10. Hungary	**0.043**	**-0.208**
11. Italy	**-0.072**	**0.743**
12. Netherlands	**-0.015**	**-0.011**
13. Norway	**-0.242**	**0.243**
14. Slovakia	**-0.711**	**-0.428**
15. Slovenia	**-0.630**	**0.010**
16. Spain	**-1.132**	**-0.055**
17. Turkey	**-0.649**	**0.249**
Stress and Fit measures Stress: 0.0373 Tucker’s coefficient of congruence: 0.98112		

Figure 2.7: Common Space Objects Points for The Seventh Variables combination



As shown in Table 2.18, the stress value of this model was (0.0373<0.050) which indicates that this model is a good fit. From Table 2.18, it can be noticed that countries located in the first dimension; Austria, Belgium and Croatia are similar to each other. Whereas, Norway and Turkey which are located in the second dimension are similar to each other. Also it can be noticed that, Germany has a high positive values in the both dimensions, i.e. it has a value of (0.809) in the first dimension and a value of (0.812) in the second dimension which means that Germany neither can be in the first dimension nor can be in the second dimension.

According to MDS analysis results shown in Table 2.18 and Figure 2.7, we can group countries to two group as follows;

Group 1: Austria, Belgium, Croatia, Czech Republic, Denmark, France, Great Britain and Hungary.

Group 2: ***Finland, Italy, Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey***

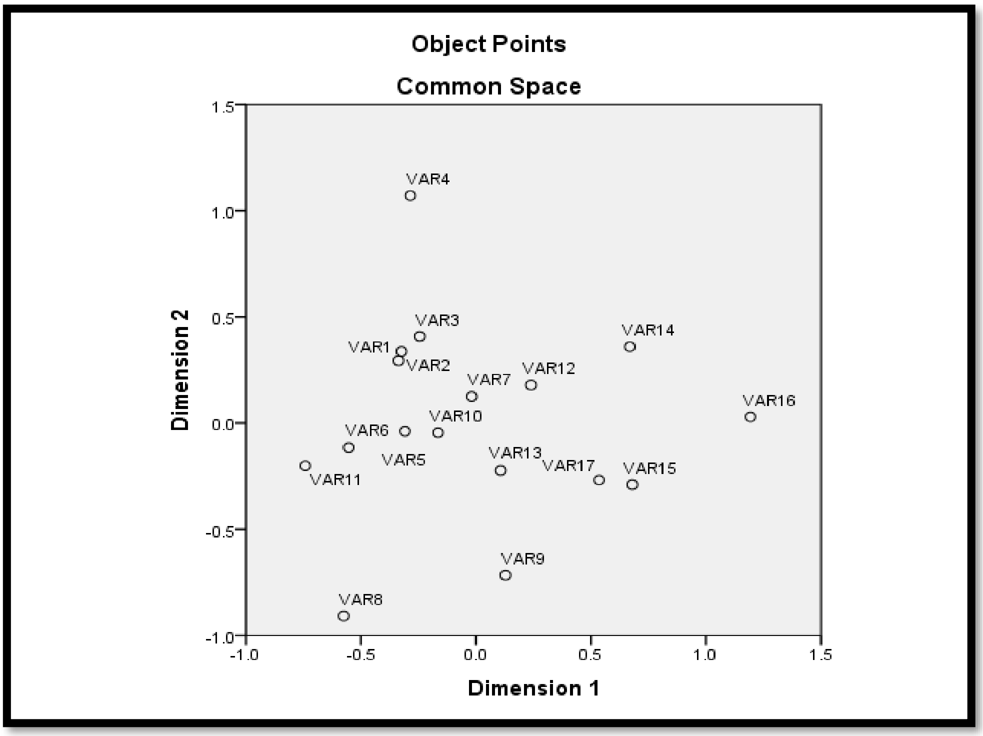
8. The Eighth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA)

This variables combination contains four economic indicators (GDP, GNI, PD, SA) and asphalt variables (x1, x2, y1, y2). MDS analysis was performed to group countries by using the data of each variable of this variables combination. Table 2.19 and Figure 2.8 show the results of implementing MDS on this variables combination.

Table 2.19: Stimulus Coordinates of Using The Eighth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA)

Countries	Dimensions	
	1	2
1. Austria	-0.336	0.293
2. Belgium	-0.324	0.337
3. Croatia	-0.244	0.408
4. Czech Republic	-0.285	1.071
5. Denmark	-0.308	-0.037
6. Finland	-0.553	-0.115
7. France	-0.018	0.125
8. Germany	-0.574	-0.908
9. Great Britain	0.128	-0.716
10. Hungary	-0.164	-0.044
11. Italy	-0.741	-0.200
12. Netherlands	0.239	0.179
13. Norway	0.107	-0.222
14. Slovakia	0.669	0.359
15. Slovenia	0.679	-0.289
16. Spain	1.192	0.029
17. Turkey	0.535	-0.268
Stress and Fit measures Stress: 0.0414 Tucker’s coefficient of congruence: 0.979072		

Figure 2.8: Common Space Objects Points for The Eighth Variables combination



As shown in Table 2.19, the stress value of this model was (0.0414<0.05) indicating that the model is a good fit. From Table 2.19, it can be noticed that Czech Republic and Spain have the highest positive values. Also that, there is a similarity between Slovenia and Slovakia which are located in the first dimension with a distance of (0.01) from each other.

From the analysis results shown in Table 2.19 and Figure 2.8, countries can be grouped into the following:

Group 1: ***France, Great Britain, Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey.***

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Germany, Italy and Hungary.

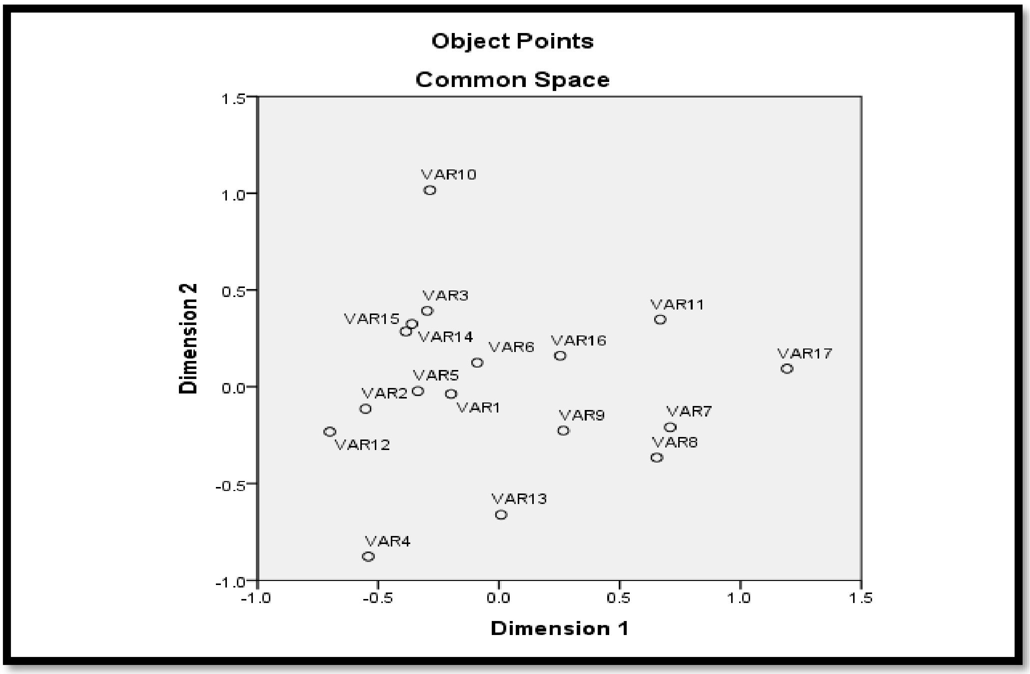
9. The Ninth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA, TP)

To perform MDS analysis, we used the data of this variables combination which contains all economic indicators (GDP, GNI, PD, SA, TP) and all asphalt variables (x1, x2, y1, y2). The analysis results of the last variables combination are shown in Table 2.20 and Figure 2.9.

Table 2.20: Stimulus Coordinates of Using The Ninth Variables Combination of (x1, x2, y1, y2 & GDP, GNI, PD, SA, TP)

Countries	Dimensions	
	1	2
1. Austria	-0.198	-0.037
2. Belgium	-0.552	-0.114
3. Croatia	-0.297	0.393
4. Czech Republic	-0.541	-0.877
5. Denmark	-0.336	-0.022
6. Finland	-0.091	0.125
7. France	0.709	-0.209
8. Germany	0.653	-0.366
9. Great Britain	0.266	-0.227
10. Hungary	-0.286	1.016
11. Italy	0.667	0.348
12. Netherlands	-0.701	-0.232
13. Norway	0.009	-0.661
14. Slovakia	-0.361	0.324
15. Slovenia	-0.386	0.286
16. Spain	0.253	0.161
17. Turkey	1.193	0.094
Stress and Fit measures Stress: 0.04019 Tucker’s coefficient of congruence: 0.97970		

Figure 2.9: Common Space Objects Points for The Ninth Variables combination



As shown in Table 2.20, the stress value of this model is (0.04019) which is below (0.05) indicating that this model is a good model. According to Table 2.20 and figure 2.9, it can be noticed that Turkey in the first dimension and Hungary in the second dimension have the highest positive values more than one. Also, there is a similarity between France, Italy and Germany which are located in the first dimension in terms of all variables used in this combination.

According to MDS analysis results shown in Table 2.20 and Figure 2.9, countries grouping can be as follows:

Group 1: ***France, Germany, Great Britain, Italy, Norway, Spain and Turkey.***

Group 2: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Netherlands, Slovakia and Slovenia.

2.5.3. A comparison between two analysis methods

After we grouped Turkey and European Union countries by using two grouping methods which are cluster analysis and MDS analysis, it is time to conduct a discussion to evaluate the analysis results from two methods used.

Table 2.21 shows all the results obtained from countries' grouping by using cluster analysis and MDS analysis.

Table 2.21: The Analysis Results of All variables Combinations

No	Variables combination	Cluster analysis		MDS analysis	
		1	2	1	2
1	x1, x2, y1, y2	Czech Republic	All other 16 countries	Spain, Slovakia, Slovenia, **Turkey**, Norway, Netherlands	Austria, Belgium, Croatia, Czech Republic, Finland, France, Great Britain, Hungary, Italy
2	x1, x2, y1, y2, SA	Austria, Belgium, Croatia, Czech Republic, Denmark, Great Britain, Hungary, Netherlands, Slovakia, Slovenia	Finland, France, Germany, Italy, Norway, Spain, **Turkey**	France, Spain, Slovakia, Slovenia, **Turkey**, Norway, Netherlands, Great Britain	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Italy
3	x1, x2, y1, y2, TP	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Netherlands, Norway, Slovakia, Slovenia	France, Germany, Great Britain, Italy, Spain, **Turkey**	Netherlands, Norway, Slovakia, Slovenia, Spain, **Turkey.**	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Hungary, Italy
4	x1, x2, y1, y2, GDP	All countries except Hungary	Hungary	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Hungary, Netherlands,	Norway, Slovakia, Slovenia, Spain, **Turkey**

				Great Britain, Italy	
5	x1, x2, y1, y2, GNI	All countries except Czech Republic	Czech Republic	Norway, Slovakia, Slovenia, Spain, **Turkey**	Austria, Belgium, Croatia, Czech Republic, Hungary, Denmark, Finland, Italy, France, Great Britain
6	x1, x2, y1, y2, GDP, GNI	All countries except Hungary	Hungary	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Hungary, Great Britain, Italy	Netherlands, Norway, Slovakia, Slovenia, Spain, **Turkey**
7	x1, x2, y1, y2, GDP, GNI, PD	All countries except Hungary	Hungary	Austria, Belgium, Croatia, Czech Republic, Denmark, France, Great Britain, Hungary	Finland, Italy, Netherlands, Norway, Slovakia, Slovenia, Spain, **Turkey**
8	x1, x2, y1, y2, GDP, GNI, PD, SA	Hungary	All countries except Hungary	France, Great Britain, Netherlands, Norway, Slovakia, Slovenia, Spain, **Turkey**	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Germany, Italy, Hungary
9	x1, x2, y1, y2, GDP, GNI, PD, SA, TP	France, Germany, Great Britain, Spain, **Turkey**	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Hungary, Netherlands, Norway, Slovakia, Slovenia	France, Germany, Great Britain, Italy, Norway, Spain, **Turkey**	Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Netherlands, Slovakia, Slovenia

From Table 2.21, it can be noticed that;

- MDS analysis provided an accurate grouping results than cluster analysis, i.e. approximately all MDS analysis results have equally divided countries into two groups.
- The accurate grouping results of using cluster analysis can be found in variables combinations no 2, 3 and9.
- In cluster analysis, variables combinations no (2, 3 and 9) have different country clusters, whereas variables combinations no (1 and 5) and (4, 6, 7 and 8) have the same country clusters.
- In MDS analysis, Turkey is located in a group contains eight countries in variables combinations no 2, 7 and8. It is also in a group contains seven countries when we used variables combination no 9. It is also in a group contains six countries when we used variables combinations no 1, 3 and 6. Also, it is in a group contains five countries when we used variables combinations no 4 and 5.
- In MDS analysis, when we used variables combinations no 2 and 8, we gained the same grouping results. Also, we gained the same grouping results, when we used variables combinations no 4 and 5.

2.6. RESULTS AND DISCUSSION

Each country has its own characteristics which might be similar or dissimilar to other countries' characteristics. Grouping countries according to similarity helps in studying and analysing these countries from different aspects and perspectives.

In this chapter, we aimed to group Turkey and the European Union countries according to asphalt pavement application by using different variables combinations consist of all asphalt variables which are (number of countries in asphalt industry, total of bitumen consumption, total production of asphalt, total length of motorways and main roads) and some economic indicators of (population density, surface area, total population, GDP and GNI). To achieve the objectives from this chapter, we preferred to use two methods of clustering which were cluster analysis and MDS analysis

(Yenilmez and Girginer, 2016; Girginer, 2016; Akkucuk, 2011). Afterwards, we made a comparison between the analysis results of two methods.

The overall results of this chapter can be summarized into the following points:

- The maximum number of variables used to analyse data was nine variables which is more than the number of variables used by (Girginer, 2013) study, and less than the number of variables used in (Akkucuk, 2011) study. Point the fact that, they both used cluster analysis and MDS analysis in their studies.
- According to data availability, we were able to obtain the data of only 17 countries which are (Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Italy, Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey). Those countries were classified into two groups by using cluster analysis and MDS analysis.
- Analysing different variables combinations by using k-mean clustering method gave the same grouping results by using variables combinations no (1 and 5) and variables combinations no (4, 6, 7 and 8). Variables combinations no (2, 3 and 9) gave different grouping results.
- Analysing different variables combinations by using MDS gave different grouping results in each analysis alternatives. Except for variables combinations (2 and 8) and for the variables combination no (4 and 5) which gave the same grouping results.
- The grouping results of using MDS analysis tends to be more accurate than the grouping results of using cluster analysis. i.e. The minimum number of countries in one group was five countries by using MDS. Whereas, when we used cluster analysis, the minimum number of countries of one group was one country.

By using different variables combinations and two kinds of analysis, we were be able to present a new model discussing the results of conducting country's grouping by focusing on asphalt pavement applications on road constructions such a model until the present time had not been discussed in any research. We think this model will have a contribution to the literature and might be considered as a reference for further researches regarding the asphalt pavement applications.

On the other hand, we can point out some limitations of this chapter. First, studying Turkey's position regarding asphalt pavements by comparing it with other European Union countries needs gathering data of all 28 EU countries, in this study we obtained only the data of 16 EU countries. Second, in this chapter we considered two methods of clustering, other clustering methods might be more accurate. Thus, analysing the same data by using other clustering methods might be considered in further researches.

CHAPTER 3

THE ASPHALT EFFICIENCY AND COST EFFICIENCY ANALYSIS

3.1. INTRODUCTION

This chapter is considered a pivotal chapter in this research study. In chapter 2, we started our analysis by grouping Turkey and EU countries in terms of asphalt pavement applications in those countries. We suggested the use of different variables combinations consist of all asphalt variables and different economic indicators by using two methods of clustering which were cluster analysis and multidimensional scaling analysis.

In this chapter, we proceeded to do a further analysis by using results obtained from chapter 2. Hence, we continued our analysis by using only one cluster. We preferred to select the group according to analysis results of MDS analysis since it provided us with a convenient grouping. By focusing on the groups that contain Turkey as one of their entities. We preferred to select the analysis results of MDS analysis for variable combinations 2 and 8 (see chapter 2...). The group consists of France, Great Britain, Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey.

The aim of this chapter is to analyse the asphalt efficiency and cost efficiency for selected cluster. At first, we suggested three scenarios of input and output variables. Then, we used data envelopment analysis models (CCR and BCC) in analysing asphalt efficiency. After that, we conducted a cost efficiency analysis for each country according to three scenarios.

3.2. LITERATURE REVIEW

By doing a literature scanning regarding the asphalt efficiency and cost efficiency, it can be noticed that measuring and evaluating the asphalt efficiency have been addressed from different perspectives. A few researches investigated the efficiency of different asphalt types and mixtures by using DEA technique such as (Li et al, 2013). They utilized data envelopment analysis (DEA) to assess the performance of three Warm Mix Asphalt (WMA) materials as contrasted with hot mix asphalt. They compared and analysed the dynamic modulus of these mixtures by performing an assessment of the overall effects of these mixtures on environmental emissions. In order to do so, they utilized the Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE). Thereby, they chose Economic output in terms of unit cost and environmental outputs including energy consumption and gaseous emissions as inputs and outputs variables for DEA. As a result of using DEA, they become able to identify the efficiency scores for each mixture which in turn helped in selecting the best satisfactory mix. They proposed that the suggested framework might aid the highway agencies in assessing and benchmarking WMA.

Most of the researches done in this area have considered efficiency assessments of highways maintenance operations. Fallah-Fini et al (2015) introduced a dynamic efficiency estimation model to assess the exhibition or performance of highway maintenance policies. The inputs and outputs variables suggested for this model were mainly concentrated on maintenance budget (for inputs) and improvements in road condition (for outputs). They assemble a miniaturized scale portrayal of asphalt impairment and reestablishment procedures and study the effect of the allocation of maintenance budgets over time. They provided efficiency estimates to differentiate the budget allocations to real ones. Also, they applied an experimental dataset of asphalt condition and maintenance expenditure throughout the years 2002-2008 comparing to seventeen miles of interstate roadways that lay in one of the regions in the province of Virginia, USA. According to results of their assessments, they suggested that highway specialists should give higher priorities to preventive maintenance than corrective maintenance. They arrived to a conclusion that by applying preventive maintenance, the highway specialists can adequately diminish the requirement for future corrective maintenance with a low cost.

Ozdek et al (2010) presented the efficiency estimation structure or framework and explicitly gave an overview of the data and modeling problems come across Virginia Department of Transportation’s case for the maintenance of bridges in the initial stages of implementing the framework. They designed this framework to consider the impacts of environmental factors such as; climate, location and etc. and operational factors such as; traffic, load and etc. on overall efficiency.

Rouse and Chiu (2009) concentrated on domestic street features of the roadways systems. The aim of their study was to evaluate how, efficiently, effectively and economically the 73 Territorial Local Authorities (TLAs) in New Zealand have maintained their respective domestic street. They joined measures of quality, quantity and cost with nondiscretionary measures of environmental factors. In their study, they utilized all these measures in Data Envelopment Analysis to assess each TLA's performance regarding efficiency, effectiveness and economy. Their investigation results demonstrated that, TLAs that have superior performance on each of the three estimates gave a best practice sign of the ideal maintenance activity mix to be adopted. In addition, the best practice blend or mix of expenditure was 59% routine maintenance, 27% resealing and 14% recovery or rehabilitation.

Kazakov et al (1989) is another study done in measuring the highway maintenance patrol efficiency. They introduced a framework to assess the efficiency of a group of highway maintenance patrols. They used data envelopment analysis (DEA) method to structure Ontario model. Their investigation focused mainly on the inputs and outputs variables that were suitable for use in assessing maintenance patrols.

Moreover, measuring highway efficiency in general has been considered in some studies. Sarmento et al (2017) assessed the efficiency of seven roadways projects in Portugal over the previous decade by using Data Envelopment Analysis and the Malmquist productivity and efficiency indices. They utilized and compared two types of efficiency which are technical and technological efficiency and they noticed that most roadways face a decrease after some time in the two types of efficiency. Also, they pointed that this decrease was for the most part because of an expansion in operating and maintenance costs, follow up investments and a decrease in traffic. A few roadways just encountered a decrease in technological efficiency after a reduction in traffic. Also, by controlling for scale efficiencies, they found an absence of unadulterated technical efficiency in roadways because it is not subject to competitive environment, which in turn led to an absence of motivators for better management. In addition, they pointed that the economic crisis in Portugal have diminished traffic that farther adds to inefficiency.

Fu et al (2013) utilized (CCR and BBC) models of Data Envelopment Analysis to make an experimental investigation of the efficiency of China's roadways systems separately regarding freight and passenger transport. The consequence of this investigation uncovered that 64.5% of provincial roadways systems show diminishing returns to scale. The non-parametric test demonstrated that there was no noteworthy contrast in regional management levels and that 45% of provincial roadways systems were inefficient in their management levels. Furthermore, they directed a super efficiency examination to rank the efficiency of roadway systems.

As result of this literature scanning, it can be noticed that there has been a lack of attention for measuring asphalt cost efficiency. Also that, most of the researches done in this area concentrated on measuring the efficiency of highways and highways maintenance.

3.3. RESEARCH OBJECTIVE

The main objective of this chapter is to analyse asphalt efficiency[2] and cost efficiency[3] for the second country cluster consists of (France, Great Britain, Netherlands, Norway, Slovakia, Slovenia, Spain and Turkey). Under this major aim, there are sub aims can be summarized as follows:

- Determining input and output variables related to asphalt pavement applications and gathering data related to those variables.
- Analysing asphalt efficiency according to different scenarios of input and output variables by using two models of output-oriented Data Envelopment Analysis (CCR and BCC) and presenting analysis results and discussion.
- Calculating the potential improvement values for inefficient countries in the two models and according to different scenarios.
- Analyzing asphalt cost efficiency by using cost variables data related to road transport infrastructure.
- Calculating asphalt cost efficiency ratios by dividing efficiency ratio for each country by cost ratio for each country.

[2] Efficiency is the proportion of outputs to inputs.
[3] Cost efficiency refers to the act of saving money by preforming activities in a better way.

- Ranking countries according to results of cost efficiency ratios and presenting results and discussion.

3.4. METHODOLOGY

In order to achieve this chapter objectives, we need to conduct a brief discussion about the methods that will be used in the data analysis. First of all, we need to clarify some of concepts that are usually used interchangeable such as performance, productivity, efficiency and effectiveness.

The proportion of outputs to inputs is usually used to mean both efficiency and productivity. while performance is viewed as a more extensive term consolidating efficiency and productivity in generally speaking accomplishment (Adam and Ebert, 1986). Productivity can be defined by the amount individuals, firm, or nations produce (i.e. outputs) depends on the amount of input and the efficiency with which those inputs are transformed into the desired output. The proportion of output to input is considered a measure used to calculate the relative efficiency of the process which is often referred to as productivity (Dilworth, 1989). Productivity can be measured using total item basis or on a partial item basis. Total item productivity is the proportion of outputs to overall items of inputs:

$$Productivity = \frac{Outputs}{Labour+Capital+Material+Energy} \quad (3.1)$$

If the proportion of outputs was to one, two, or three of the inputs (such as; materials or labour or any other input), in this case it becomes a partial item basis to measure the productivity (Adam and Ebert, 1986).

On the other hand, the difference between effectiveness and efficiency is that the effectiveness is acquiring the wanted outcomes; outcomes might be the amount of output or the recognized quality or both. While, the efficiency is acquiring the specific output with the least use of inputs. Nevertheless, the firms face different obstacles regarding the quality of products and customer satisfaction, so productivity measures can be adjusted to catch and deal with different issues that any firm might face. In some cases, the firms might express the productivity as follows;

$$Productivity = \frac{Effectiveness}{Effeciency} \quad \text{or} \quad \frac{Value\ to\ customer}{cost\ to\ producer} \qquad 3.2$$

Where effectiveness is doing the correct or right things, and efficiency is doing things correctly or right (Chase and Aquilano, 1992).

Before conducting our methodology discussion, we also need to distinguish between three important sorts of efficiency which are; The technical efficiency, Allocative efficiency and Economic efficiency.

Koopmans (1951) described the technical efficiency as a circumstance in which it is considered difficult to deliver a greater amount of any output without manufacturing less of some other output or even utilizing a greater amount of some input. While the technical efficiency has to do with how well the firm figured out how to utilize their inputs to obtained outputs, allocative efficiency estimates the firm's capability to get the highest profit under the current market prices for both inputs and outputs. On the other hand, the economic or cost efficiency contains the technical and allocative efficiency. Which demonstrates the negative affect on cost efficiency, if one of these two sorts of efficiency were low. Hence, so as to acquire the economic efficiency both the allocative and technical efficiencies should be at solidarity and the lower these two ratios are the lower the economic efficiency would be (Dobrowsky, 2013).

In the upcoming sections of research methodology, we will discuss the Data Envelopment analysis as a technique used to measure the efficiency. After that, we will discuss the methodology used for cost efficiency analysis.

3.4.1. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is considered a new approach for assessing the performance of a set of structures generally refers to as Decision Making Units (DMUs) which convert different contributions to various yields. The meaning of a DMU is nonexclusive and adaptable. The late years have witnessed an incredible assortment of utilizing DEA for assessing the exhibitions of numerous sorts of elements occupied with a wide range of tasks in various settings in a wide range of nations. For example, the DEA applications have utilized DMUs of different structures to assess the performance, those structures can be countries, firms, banks and etc (Cooper et al, 2011).

The initial presentation of data envelopment analysis as nonparametric technique to measure the productive efficiency for DMUs was by Charnes, cooper and Rhodes in (1978). This model depended on the supposition of constant return to scale until it was changed by Banker et al (1984). The new supposition developed by Banker et al (1984) dependent on variable return to scale. Both DEA models have led to the existence of input and output oriented models (Kočišová, 2016). The input-oriented model concerns with reducing or minimizing inputs for an ideal degree of output to be accomplished, and output-oriented model concerns with increasing or maximizing the outputs while input is kept at a fixed level. Both the input and output oriented models simply look for increasing the outputs, decreasing the inputs and thereby achieving the efficiency (Rajasekar and Deo, 2014).

In DEA models, we assess n productive units or Decision-Making Units (DMUs), where each one of DMUs takes m different inputs to produce s different outputs. DEA models is used to measure the efficiency of productive unit DMU_q which depends on maximizing its efficiency rate. Point the fact that, this case is subject to the condition that the efficiency rate of any other units in the population must not be greater than 1. The models must include all characteristics considered, i.e. the weights of all inputs and outputs must be greater than zero. This model can be characterized as a linear divisive programming model (Vincova, 2005):

$$maximize \qquad \frac{\sum_i u_i y_{iq}}{\sum_j v_j x_{jq}} \qquad 3.3$$

$$subject\ to \qquad \frac{\sum_i u_i y_{iq}}{\sum_j v_j x_{jq}} \leq 1 \qquad k = 1, 2, \dots, n$$

$$u_i \geq \in \qquad i = 1, 2, \dots, s$$

$$v_j \geq \in \qquad j = 1, 2, \dots, m$$

The suggested model can be transformed into a linear programming model 3.4 and expressed in a matrix form:

$$maximize \qquad z = u^T Y_q \qquad (3.4)$$

$$subject\ to \qquad v^T X_q = 1$$

$$u^T Y_q - v^T X_q \leq 0$$

$$u \geq \in$$

$$v \leq \in$$

Model 3.4 is usually called the primary CCR model (Charnes, Cooper, Rhodes). The dual model to this can be presented as follows:

$$minimize \qquad f = \theta - \in (e^T s^+ + e^T s^-) \qquad (3.5)$$

$$subject\ to \qquad Y\lambda - s^+ = Y_q$$

$$X\lambda + s^- = \theta X_q$$

$$\lambda, s^+, s^- \geq 0$$

where $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n), \lambda \geq 0$ refers to a vector assigned to individual productive units or DMUs, s+ and s– are vectors of addition input and output variables, $e^T = (1, 1, \ldots, 1)$ and ∈ is a constant[4] greater than zero, which is normally pitched at $10^{-6}\ or\ 10^{-8}$. In evaluating the efficiency of unit DMU_q, model (3.5) seeks a virtual unit characterised by inputs $X\lambda$ and outputs $Y\lambda$, which are a linear combination of inputs and outputs of other units of the population and which are better that the inputs and outputs of unit DMU_q which is being evaluated. For inputs of the virtual unit $X\lambda \leq X_q$ and for outputs $Y\lambda \geq Y_q$. Unit DMU_q is rated efficient if no virtual unit with requested traits exists or if the virtual unit is identical with the unit evaluated, i.e. $X\lambda = X_q\ and\ Y\lambda = Y_q$.

If unit DMU is CCR efficient, then:

- the value of variable θ is zero,

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4 Economic reasoning: for any amount of output, at least a minimum quantity of every input should be utilized. If any of the inputs equals zero, the total output is zero as well.

- the values of all additional variables s+ and s– equal zero.

Consequently, unit DMU_q is CCR efficient if the optimum value of the model (3.5) objective function equals one. Otherwise, the unit is inefficient. The optimum value of the objective function f^* marks the efficiency rate of the unit concerned. The lower the rate, the less efficient the unit is compared to the rest of the population. In inefficient units θ is less than one. This value shows the need for a proportional reduction of inputs for unit DMU_q to become efficient. The advantage of the DEA model is that it advises how the unit evaluated should mend its behaviour to reach efficiency.

Models (3.4) and (3.5) are input-oriented – they try to find out how to improve the input characteristics of the unit concerned for it to become efficient. There are output oriented models as well. Such a model could be written as follows:

$$\begin{aligned} &maximize \quad && g = \emptyset - \in (e^T s^+ + e^T s^-) \\ &subject\ to \quad && Y\lambda - s^+ = \emptyset Y_q \\ & && X\lambda + s^- = X_q \\ & && \lambda,\ s^+, s^- \geq\ 0 \end{aligned} \qquad 3.6$$

This model can be interpreted as follows: unit DMU_q is CCR efficient if the optimal value of the objective function in model (3.6) equals one, $g^* \ = \ 1$. If the value of the function is greater than one, the unit is inefficient. The variable Φ indicates the need for increased output to achieve efficiency. For the optimal solution to the CCR model, the values of objective functions should be inverted, i.e. $f^* \ = \ 1/g^*$.

Models (3.4), (3.5) and (3.6) assume constant returns to scale[5]. Nevertheless, in efficiency analysis, variable returns to scale can be considered as well. In that case, models (3.5) and (3.6) need to be rewritten to include a condition of convexity $e^T \lambda \ = \ 1$. Then, they are adjusted to be BCC (Banker, Charnes, Cooper) models.

The purpose of DEA analysis is not just to define the efficiency rate of DMUs, but also to identify the target or the potential improvement values for inputs X'_q and

[5] A double increase in inputs leads to a double increase in outputs is usually refers to constant return to scale.

outputs Y'_q for an inefficient unit. These values might help the inefficient units to become efficient. Target or potential improvement values can be calculated as follows:

1. by means of productive unit or DMU vectors:

$$X'_q = X\lambda^*$$

$$Y'_q = Y\lambda^*$$

where λ* is referred to the vector of optimal variable values.

2. by means of the efficiency rate and values of additional variables s– and s+:

input-oriented CCR model:

$$X'_q = \theta X_q - s^- \qquad Y'_q = Y_q + s^+$$

output-oriented CCR model:

$$X'_q = X_q - s^- \qquad Y'_q = \emptyset Y_q + s^+$$

where θ is the efficiency rate in the input-oriented model and Φ is the efficiency rate in the output-oriented model.

3.4.2. Cost Efficiency Analysis

In order to achieve the other objective of this chapter, which is analysing cost efficiency of asphalt pavement, we need to give a brief discussion about method that we used in analysis. We followed steps presented below in order to perform cost efficiency analysis for asphalt.

1. **Step 1:** calculate cost ratio for each country

To calculate cost ratio for each country (i), we used this formula:

$$cost\ ratio\ for\ (i) = \frac{cost\ value\ of\ (i)}{total\ cost} \qquad 3.7$$

$$where \quad i \equiv country\ or\ DMU, i = France, Great\ Britain, \dots, Turkey$$

2. **Step 2:** calculate cost efficiency for each country

In order to calculate cost efficiency for each country, we used this formula:

$$cost\ efficiency\ ratio\ for\ country\ (i) = \frac{cost\ ratio\ for\ country\ (i)}{efficiency\ score\ for\ country\ (i)} \quad 3.8$$

According to equation (3.8), we can calculate cost efficiency ratio for each country by dividing cost ratio for country (i) –calculated in step 1- by efficiency score –efficiency scores results obtained from using two model of output oriented DEA (CCR and BCC)- for country (i).

3. **Step 3**: rank countries

After calculating cost efficiency ratios for each country, we can rank countries according to results of cost efficiency ratios. The country has the lowest cost efficiency ratio, it will be ranked by number 1, which indicates that if the efficiency for this country increases by one unit, the increase in cost will be by the same amount of cost efficiency ratio. Because, this country has the lowest increase in cost.

In section 5, we discussed the applications of two methods of analysis presented in this section.

3.5.THE ASPHALT EFFICIENCY AND COST EFFICIENCY ANALYSIS

In this part of our study, we considered analysing asphalt efficiency by using Data Envelopment Analysis. After that by using cost efficiency analysis, we were be able to calculate asphalt cost efficiency ratios for selected country cluster.

In order to perform the two methods of analysis, we preferred to used variables related to asphalt application so that we can analyse asphalt efficiency and cost efficiency for country. Table 3.1 shows all variables used in calculating efficiency scores and cost efficiency ratios and source of data. Table 3.2 on the other hand, shows the data of asphalt input and output variables for 2016 dataset. The reason for choosing these variables shown in Table 3.1 is that in order to evaluate asphalt efficiency for any country, we need to know about inputs and outputs used in asphalt pavement process so that we can calculate efficiency scores for each country according asphalt data provided by each country.

Table 3.1: Variables Used in Asphalt Efficiency and Cost Efficiency Analysis

Variables	Symbols	Source Of Data
Cost variables:		
• **Road infrastructure investment spending (in million €)**	**RIIS**	OECD.stat database
• **Road infrastructure maintenance spending (in million €)**	**RIMS**	OECD.stat
Inputs variables:		
• **Number of companies in asphalt industry (production and laying)**	**X1**	EAPA
• **Total of bitumen consumption (in million tonnes)**	**X2**	EAPA
Outputs variables:		
• **Total production of asphalt (in million tonnes)**	**Y1**	EAPA
• **Total length of motorways and main roads (km)**	**Y2**	Eurostat and Statista database

Table 3.2: Data of Inputs and Outputs Variables

Countries (DMUs)	Inputs variables		Outputs variables	
	X1	**X2**	**y1**	**y2**
1. France	30	2.50	33.6	11612
2. Great Britain	19	1.295	22.0	52874.33
3. Netherlands	17	0.29	8.2	5355
4. Norway	13	0.38	7.2	11087
5. Slovakia	2	0.10	1.9	4353
6. Slovenia	13	0.08	1.6	6225.2
7. Spain	125	0.60	13.1	30390
8. Turkey	312	2.93	40.4	33648

However, the input oriented is considered less relevant in estimation the capacity utilization not so like output-oriented models, in our analysis we considered the output-oriented models to achieve analysis objectives. In another word, we preferred to use output-oriented models to measure asphalt efficiency.

The framework of research analysis was designed as follows: At first, we analysed the asphalt efficiency by using inputs and outputs data related to selected country cluster. In this analysis we used both (CCR) and (BCC) models of Data Envelopment Analysis to define the efficient and inefficient countries in the scope of asphalt pavements. Then, we calculated the cost ratio for each country, after that we divided the results obtained from calculating cost ratio for each country by efficiency scores for each country obtained from using DEA models so that we can get cost efficiency ratio for each country. In upcoming sections, we provided a detailed presentation and discussion about using DEA models for measuring asphalt efficiency and how to calculate cost efficiency ratios for each country.

3.5.1. Efficiency analysis (DEA)

In this section, we presented different scenarios to analyse the asphalt efficiency for DMUs, at the first we used (x1 and x2) as input variables and (y1 and y2) as output variables. Then, in the second scenario we used (x1 and x2) as an input variable and (y1) as an output variable. In the third scenario, we used (x1 and x2) as inputs variables along with (y2) as an output variable. In each scenario, we evaluated DMUs performance in asphalt pavements by using output-oriented models of DEA, in each scenario we preferred to use (CCR) and (BCC) models of DEA. We can present those scenarios as follows:

Scenario 1	**x1, x2, y1, y2**
Scenario 2	x1, x2, y1
Scenario 3	x1,x2, y2

3.5.1.1. Scenario 1

In this scenario, we used (x1 and x2) as input variables and (y1 and y2) as output variables. Table 3.3 shows the efficiency scores and reference frequencies for eight countries.

Table 3.3: The Efficiency Scores and Reference Frequencies For DMUs (CCR)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovakia	100	Efficient	1
Slovenia	100	Efficient	3
Great Britain	100	Efficient	1
Netherlands	100	Efficient	3
France	96.73	Not Efficient	0
Spain	93.66	Not Efficient	0
Norway	84.68	Not Efficient	0
Turkey	49.88	Not Efficient	0

As shown in Table 3.3, when we used (CCR) model, Slovakia, Slovenia, Great Britain and Netherlands were efficient by 100%. The efficiency score for France was 96.73%, for Spain was 93.66% and for Norway was 84.68%. Turkey on the other hand, had the least efficiency of 49.88%.

For inefficient DMUs -with efficiency score below 100%- potential improvement values were calculated. Table 3.4 shows the potential improvement values of inefficient countries by using (CCR) mode.

Table 3.4: The Potential Improvement Values for Inefficient Countries (CCR)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
France	input	X1	30.00	30.00	00.00	Great Britain
		X2	2.50	2.04	-18.21	
	output	Y1	33.60	34.74	03.38	
		Y2	11612.00	83485.78	618.96	
Spain	input	X1	125.00	72.57	-41.94	Netherlands Slovenia
		X2	0.60	0.60	00.00	
	output	Y1	13.10	13.99	06.76	
		Y2	30390.00	32445.68	06.76	
Norway	input	X1	13.00	13.00	00.00	Netherlands Slovakia Slovenia
		X2	0.38	0.38	00.00	
	output	Y1	7.20	8.50	18.09	

		Y2	11087.00	13092.49	18.09	
Turkey	input	X1	312.00	195.12	-37.46	Netherlands Slovenia
		X2	2.93	2.93	00.00	
	output	Y1	40.40	80.99	100.46	
		Y2	33648.00	67451.76	100.46	

According to Table 3.4, in order to reach efficiency level, France has to increase its outputs by 3.38% for y1 and 618.96% for y2 and to decrease its input by 18.21% for x2; Spain has to increase its outputs by 6.76% for y1 and y2 and to decrease its input by 41.94%; Norway has to increase its outputs by 18.09% for y1 and y2; whereas Turkey has to increase its outputs by %100.46 for y1 and y2 and to decrease its input by %37.46 for x1.

Now, we can see the results of output-oriented model by using (BCC) mode. Table 3.5 shows the efficiency scores of DMUs and Table 3.6 shows the potential improvement values of inefficient DMUs.

Table 3.5: The Efficiency Scores And Reference Frequencies For DMUs (BCC)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovakia	100	Efficient	1
Slovenia	100	Efficient	1
Netherlands	100	Efficient	1
Spain	100	Efficient	0
Great Britain	100	Efficient	1
Turkey	100	Efficient	0
France	100	Efficient	0
Norway	49.88	Not Efficient	0

As shown in Table 3.5, all countries were efficient excepts Norway with efficiency score of only %49.88.

Table 3.6: The Potential Improvement Values Of Inefficient Countries (BCC)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
Norway	input	X1	13.00	13.00	00.00	Great Britain Netherlands Slovakia
		X2	0.38	0.38	00.00	
	output	Y1	7.20	8.16	13.40	
		Y2	11087.00	12572.21	13.40	

						Slovenia

According to Table 3.6, Norway has to increase its outputs by 13.40% of y1 and y2 in order to reach efficiency level by taking Great Britain, Netherland, Slovakia and Slovenia as references.

3.5.1.2. Scenario 2

In scenario 2, we used (x1 and x2) as an input variables and (y1) as an output variable. Table 3.7 shows the efficiency scores and reference frequencies for DMUs.

Table 3.7: The Efficiency Scores and Reference Frequencies for DMUs (CCR)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovakia	100	Efficient	1
Great Britain	100	Efficient	1
Netherlands	100	Efficient	4
France	96.73	Not Efficient	0
Norway	84.54	Not Efficient	0
Spain	77.22	Not Efficient	0
Slovenia	70.73	Not Efficient	0
Turkey	48.76	Not Efficient	0

According to (CCR) model results shown in Table 3.7, the efficiency scores for Slovakia, Great Britain and Netherlands were 100%. Efficiency score for France was 96.735%, for Norway was 84.54%, for Spain was 77.22%, for Slovenia was 70.73% and Turkey had the least efficiency score of 48.76%.

Moreover, we were be able to calculate the potential improvement values for inefficient DMUs which had efficiency scores below 100%. Table 3.8 shows the potential improvement values of inefficient countries by using output-oriented model of (CCR).

Table 3.8: The Potential Improvement Values for Inefficient Countries (CCR)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
France	input	X1	30.00	30.00	00.00	

		X2	2.50	2.04	-18.53	Great Britain
	output	Y1	33.60	34.74	03.38	
Norway	input	X1	13.00	13.00	00.00	Netherlands Slovakia
		X2	0.38	0.38	00.00	
	output	Y1	7.20	8.52	18.29	
Spain	input	X1	125.00	35.17	-71.86	Netherlands
		X2	0.60	0.60	00.00	
	output	Y1	13.10	16.97	29.51	
Slovenia	input	X1	13.00	4.69	-63.93	Netherlands
		X2	0.08	0.08	00.00	
	output	Y1	1.60	2.26	41.38	
Turkey	input	X1	312.00	171.76	-44.95	Netherlands
		X2	2.93	2.93	00.00	
	output	Y1	40.40	82.85	105.07	

According to Table 3.8, in order to reach efficiency level, France has to increase y1 by 3.38% and decrease x2 by 18.53%; Norway has to only increase y1 by 18.29%; Spain has to increase y2 by 29.51% and decrease x1 by 71.86%; Slovenia has to increase y1 by 41.38% and decrease x1 by 63.93% and Turkey has to increase y1 by 105.07% and decrease x1 by 44.95%.

Furthermore, the result of using (BCC) model of DEA are shown in Table 3.9 and Table 5.10. Table 5.9 shows the efficiency scores of DMUs and Table 3.10 shows the potential improvement values of inefficient countries.

Table 3.9: The Efficiency Scores And Reference Frequencies For DMUs (BCC)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovenia	100	Efficient	0
Slovakia	100	Efficient	1
Netherlands	100	Efficient	1
Spain	100	Efficient	0
Turkey	100	Efficient	0
France	100	Efficient	0
Great Britain	100	Efficient	1
Norway	85.81	Not Efficient	0

As shown in Table 3.9, efficiency scores for all countries were 100% except Norway. The efficiency score for Norway were 85.81% but it might reach the efficiency level, if it increases y1 by 16.53% as shown in Table 3.10.

Table 3.10: The Potential Improvement Values for Inefficient Countries (BCC)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
Norway	input	X1	13.00	13.00	00.00	Great Britain Netherlands Slovakia
		X2	0.38	0.38	00.00	
	output	Y1	7.20	8.39	16.53	

3.5.1.3. Scenario 3

In this scenario, we used (x1 and x2) as an input variable and (y2) as an output variable. Table 3.11 shows the efficiency scores and reference frequencies for DMUs.

Table 3.11: The Efficiency Scores And Reference Frequencies For DMUs (CCR)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovakia	100	Efficient	3
Slovenia	100	Efficient	4
Great Britain	100	Efficient	1
Spain	65.09	Not Efficient	0
Norway	62.14	Not Efficient	0
Netherlands	34.96	Not Efficient	0
Turkey	17.85	Not Efficient	0
France	13.91	Not Efficient	0

According to (CCR) model results, the efficiency scores for Slovakia, Slovenia and Great Britain were 100%. The efficiency score for Spain was 65.09% and for Norway was 62.14%. Netherlands, Turkey and France had the least efficiency scores.

For DMUs having efficiency scores below 100%, potential improvement values were calculated. Table 3.12 shows the potential improvement values for inefficient DMUs.

Table 3.12: The Potential Improvement Values for Inefficient Countries (CCR)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
Spain	input	X1	125.00	97.50	-22.00	Slovenia
		X2	0.60	0.60	00.00	

	output	Y2	30390.00	46689.00	53.63	
Norway	input	X1	13.00	13.00	00.00	Slovakia Slovenia
		X2	0.38	0.38	00.00	
	output	Y2	11087.00	17840.62	60.91	
Netherlands	input	X1	17.00	17.00	00.00	Slovakia Slovenia
		X2	0.29	0.29	00.00	
	output	Y2	5355.00	15318.38	186.06	
Turkey	input	X1	312.00	312.00	00.00	Slovakia Slovenia
		X2	2.93	2.93	00.00	
	output	Y2	33648.00	188510.05	460.24	
France	input	X1	30.00	30.00	00.00	Great Britain
		X2	2.50	2.04	-18.53	
	output	Y2	11612.00	83485.78	618.96	

As shown in Table 3.12, to be able to reach efficiency level, Spain has to increase y2 by 53.63% and decrease x1 by 22%; Norway has to only increase y2 by 60.91%; Netherlands has to only increase y2 by 186.06%; Turkey has to increase its output y2 (Total length of motorways and main roads) by %460.42 and France has to increase y2 by 618.96% and decrease x2 by 18.53%.

Moreover, by using output-oriented model of (BCC), we gained the results presented in Table 3.13 and Table 3.14. Table 3.13 shows the efficiency scores and reference frequencies for DMUs whereas Table 3.14 shows the potential improvement values for inefficient DMUs.

Table 3.13: The Efficiency Scores and Reference Frequencies for DMUs (BCC)

DMUs	Efficiency scores	Efficiency status	Reference frequencies
Slovakia	100	Efficient	1
Slovenia	100	Efficient	2
Spain	100	Efficient	1
Great Britain	100	Efficient	4
Turkey	63.64	Not Efficient	0
Norway	63.58	Not Efficient	0
Netherlands	37.10	Not Efficient	0
France	21.96	Not Efficient	0

From Table 3.13, we can notice that, the efficiency scores for Slovakia, Slovenia, Spain and Great Britain were 100%. Whereas, the efficiency score for Turkey was 63.64% and for Norway was 63.58%. Also, we can notice that Netherlands and France had the least efficiency scores.

Table 3.14: The Potential Improvement Values of Inefficient Countries (BCC)

DMUs	variables		Actual values	Target values	Potential improvement values (%)	Peer references
Turkey	input	X1	312.00	19.00	-93.91	Great Britain
		X2	2.93	1.29	-55.97	
	output	Y2	33648.00	52874.33	57.14	
Norway	input	X1	13.00	13.00	00.00	Great Britain Slovakia Slovenia
		X2	0.38	0.38	00.00	
	output	Y2	11087.00	17436.83	57.27	
Netherlands	input	X1	17.00	17.00	00.00	Great Britain Slovenia Spain
		X2	0.29	0.29	00.00	
	output	Y2	5355.00	14432.66	169.52	
France	input	X1	30.00	19.00	-36.67	Great Britain
		X2	2.50	1.29	-48.40	
	output	Y2	11612.00	52874.33	355.34	

According to Table 3.14, in order to reach efficiency level, Turkey has to increase y2 by 57.14% and decrease both its inputs by 93.91% for x1 and by 55.97% for x2; Norway has to increase only its output y2 by 57.27%; also Netherlands had to increase its output by 169.52% and France has to increase its output by 355.34% and decrease inputs by 36.67% for x1 and 48.40% for x2.

3.5.2. Cost Efficiency Analysis for DMUs

In this section, we performed a cost efficiency analysis to decide which country operates with the least cost regarding asphalt pavement applications. In the previous section we were be able to analyse and calculate efficiency scores for the European countries located in the second group. Here at first, we will calculate the cost ratio for each country or DMU by recalling cost variables previously pointed to in Table 3.1 we can again show them as follows;

Road transportation infrastructure investment spending (RTIIS)	**Source of data: OECD database, (schroten et al, 2019).**
Road transportation infrastructure maintenance spending (RTIMS)	

By using the data of these two cost variables, we were be able to calculate the total cost by summing the cost of RTIIS with the cost of RTIMS for each country according to steps shown in the section 4.2. After that, we obtained total cost by summing the cost values (Table 3.15). Table 3.15 shows the results of cost values of summing the data of RTIIS with the data of RTIMS

Table 3.15: RTIIS & RTIMS data And Total Cost Results for DMUs

DMUs	RTIIS (€)	RTIMS (€)	Cost values
France	9,257,455,833	2,430,850,000	11,688,305,833
Great Britain	8,559,910,856	2,504,103,065	11,064,013,921
Netherlands	7,700,000,000*	1,400,000,000*	9,100,000,000
Norway	3,427,529,136	1,900,000,000*	5,327,529,136
Slovakia	751,418,000	215,000,000	966,418,000
Slovenia	100,000,000	138,000,000	238,000,000
Spain	3,924,000,000	3,200,000,000*	7,124,000,000
Turkey	7,329,613,591	230,053,550	7,559,667,141
Total cost			**53,067,934031**

*****source of data (schroten et al, 2019) study of "overview of transport infrastructure expenditures and costs".

Furthermore, by using the cost results shown in Table 3.15, we can recall equation 3.7 to calculate the cost ratio for each country, which can be shown again as follows:

$$cost\ ratio\ for\ (i) = \frac{cost\ value\ of\ (i)}{total\ cost}$$

$$where \quad i \equiv country\ or\ DMU, i = France, Great\ Britain, \ldots, Turkey$$

When we applied this equation on the cost results shown in Table 3.15, we can get the cost ratio for each country (Table 3.16). Table 3.16 shows the results of cost ratio that we needed to calculate cost efficiency ratios for each country.

Table 3.16: The Results of Cost Ratios For DMUs

DMUs	Cost values (€)	Cost ratio (%)
France	11,688,305,833	22.03
Great Britain	11,064,013,921	20.85
Netherlands	9,100,000,000	17.15
Norway	5,327,529,136	10.04
Slovakia	966,418,000	1.82

Slovenia	238,000,000	0.45
Spain	7,124,000,000	13.42
Turkey	7,559,667,141	14.24
Total	**53,067,934031**	**100**

Thus, In order to calculate the asphalt cost efficiency for each DMU and to define which country operates with the minimum cost related to its asphalt pavement applications, at first we recalled the results of efficiency scores for each scenario that had been previously calculated by using DEA models (i.e. for scenario 1 we needed to recall (Table 3.3 and Table 3.5), For scenario 2 we recalled (Table 3.7 and Table (3.9), for scenario 3 we recalled (Table 3.11 and Table 3.13). Then, we were be able to calculate the cost efficiency for each country by recalling equation 3.8 shown below;

$$cost\ efficiency\ ratio\ for\ country\ (i) = \frac{cost\ ratio\ for\ country\ (i)}{efficiency\ score\ for\ country\ (i)}$$

Now, we can present the results of applying this equation and obtaining cost efficiency ratios for the three scenarios.

3.5.2.1. Scenario 1

In analysing asphalt efficiency for DMUs, we used two models of DEA (CCR and BCC) in order to get efficiency scores for each DMUs. In scenario 1, we used (x1 and x2) as input variables and (y1 and y2) as output variables to get efficiency scores for each country. Our aim in this section is to calculate cost efficiency for DMUs. In order to do so we needed to recall efficiency scores results of (CCR) model (Table 3.3) and (BCC) model (Table 3.5) along with the results of cost ratios (Table 3.16) and by implementing equation 3.2, we were be able to get the results of cost efficiency analysis for scenario 1 as shown in Table 3.17;

Table 3.17: The Results Of Cost Efficiency Analysis for Scenario 1

Country	a cost ratios (%)	b Efficiency scores (%) (CCR)	c Efficiency scores (%) (BCC)	d Cost efficiency ratios and ranking (CCR) d=a/b	e Cost efficiency ratios and ranking (BCC) e=a/c
France	22.03	96.73	100	22.77 (7)	22.03 (8)
Great Britain	20.85	100	100	20.85 (6)	20.85 (7)
Netherlands	17.15	100	100	17.15 (5)	17.15 (5)
Norway	10.04	84.68	49.88	11.85 (3)	20.12 (6)
Slovakia	1.82	100	100	1.82 (2)	1.82 (2)
Slovenia	0.45	100	100	0.45 (1)	0.45 (1)
Spain	13.42	93.66	100	14.32 (4)	13.42 (3)
Turkey	14.24	49.88	100	28.54 (8)	14.24 (4)

Table 3.17 shows the results of calculating the cost efficiency ratio for each country. From Table 3.17, we can notice that Slovenia has the lowest cost efficiency ratio in two models (CCR) and (BCC) which means that if the efficiency for Slovenia increases by one unit, the cost related to it will increase by only 0.45% which is the lowest increase in the cost. According to (CCR) model; if the efficiency for Turkey increases by one unit, the cost related to it will then increase by 28.54% which is the highest increase in the cost. Though, according to (BCC) model it was ranked no 4. On the other hand, if the efficiency for France increases by one unit, the cost related to it will increase by 22.03% which is the highest increase in the cost according to (BCC) model.

3.5.2.2. Scenario 2

In this scenario we used (x1 and x2) as input variables and (y1) as output variable to get efficiency scores by using (CCR) and (BCC) models. Here, we calculated cost efficiency for each DMU. We needed to recall the efficiency scores results of using (CCR) model (Table 3.7), and (BCC) model (Table 3.9) along with the results of cost ratios (Table 3.16) and by implementing equation 3.2, we got the results of cost efficiency analysis for scenario 2 as shown in Table 3.18.

Table 3.18: The Results of Cost Efficiency Analysis for Scenario 2

Country	a cost ratios (%)	b Efficiency scores (%) (CCR)	c Efficiency scores (%) (BCC)	d Cost efficiency ratios and order (CCR) d=a/b	e Cost efficiency ratios and order (BCC) e=a/c
France	22.03	96.73	100	22.77 (7)	22.03 (8)
Great Britain	20.85	100	100	20.85 (6)	20.85 (7)
Netherlands	17.15	100	100	17.15 (4)	17.15 (6)
Norway	10.04	84.54	85.81	11.87 (3)	11.70 (3)
Slovakia	1.82	100	100	1.82 (2)	1.82 (2)
Slovenia	0.45	70.73	100	0.63 (1)	0.45 (1)
Spain	13.42	77.22	100	17.37 (5)	13.42 (4)
Turkey	14.24	48.76	100	29.20 (8)	14.24 (5)

Table 3.18 shows the results of calculating the cost efficiency ratios for each DMU. From Table 3.18, it can be noticed that Slovenia has the lowest cost, when we applied equation 5.2 by using (CCR) and (BCC) models results. Hence, according to cost efficiency analysis results of (CCR) model, if the efficiency for Slovenia increases by one unit, the cost related to it will increase by 0.63% which is the lowest increase in the cost in this model. Also, it can be noticed that according to (BCC) model results for Slovenia, if the asphalt efficiency for Slovenia increases by one unit, the cost related to it will increase by 0.45% which is the lowest increase in cost in this model. On the other hand, if the efficiency for Turkey increases by one unit, the cost related to it will then increase by 29.20% which is the highest increase in cost according to (CCR) model. Moreover, if the efficiency for France increases by one unit, the cost related to it will increase by 22.03% which is the highest increase in cost observed when we used (BCC) model results in calculating cost efficiency ratios.

3.5.2.3. Scenario 3

In this scenario we used (x1 and x2) as input variables and (y2) as output variable to get the efficiency scores for DMUs by using (CCR) and (BCC) models results. In order to calculate cost efficiency ratios for DMUs, we needed to recall the results of (CCR) model (Table 3.11) and (BCC) model (Table 3.13) along with the results of cost ratio (Table 3.16) and by implementing equation 3.2, we got the results of cost efficiency analysis for scenario 3 as shown in Table 3.19.

Table 3.19: The Results of Cost Efficiency Analysis For Scenario 3

Country	a cost ratios (%)	b Efficiency scores (%) (CCR)	c Efficiency scores (%) (BCC)	d Cost efficiency ratios and order (CCR) d=a/b	e Cost efficiency ratios and order (BCC) e=a/c
France	22.03	13.91	21.96	158.37 (8)	100.31 (8)
Great Britain	20.85	100	100	20.85 (5)	20.85 (5)
Netherlands	17.15	34.96	37.10	49.05 (6)	46.22 (7)
Norway	10.04	62.14	63.58	16.15 (3)	15.79 (4)
Slovakia	1.82	100	100	1.82 (2)	1.82 (2)
Slovenia	0.45	100	100	0.45 (1)	0.45 (1)
Spain	13.42	65.09	100	20.61 (4)	13.42 (3)
Turkey	14.24	17.85	63.64	79.77 (7)	22.37 (6)

Table 3.19 shows the results of calculating the cost efficiency ratios according to efficiency scores results from using (CCR) and (BCC) models. From Table 3.19, it can be noticed that if the efficiency for Slovenia increases by one unit, the cost related to it will increase by 0.45% which is the lowest increase in the cost in the two models. On the other hand, if the asphalt efficiency for France increases by one unit, the cost related to it will increase by 158.37% according to (CCR) model results and by 100.31% according to (BCC) model results, in both models it is considered the highest increase in cost.

3.6. RESULTS AND DISCUSSION

The main purpose from this chapter was to analyse asphalt pavement efficiency and cost efficiency for the second country cluster which obtained from the analysis results of chapter 2. In order to achieve our objectives from this chapter, at first we analysed asphalt efficiency for eight countries by suggesting different scenarios of input and output variables by using output oriented model of DEA, we preferred to use (CCR) and (BCC) models of DEA as both of them were also preferred to be use by (Fu et al, 2013). Then, we moved further and conducted a cost efficiency analysis by using efficiency ratios calculated in performing DEA. The results from implementing two methods of analysis can be summarized as follows:

- **Results discussion regarding asphalt efficiency analysis:**
  - The results of using (BCC) model are considered more accurate than results of using (CCR) model. By using (BCC) model doubling input produces less than doubling outputs which is considered more realistic than (CCR) model results when outputs directly reflect input levels. That is why, we can notice that some countries were efficient when we used (BCC) model but inefficient when we used (CCR) model like Turkey, Spain and France in scenario 1 and 2.
  - Slovakia and Great Britain were always efficient in the three scenarios and by using two models of (CCR and BCC).
  - Norway was always inefficient in the three scenarios and by using two models of (CCR and BCC). According to potential improvement values suggested by each model, for example the results of (BCC) model for scenario 1 suggested that Norway has to increase its outputs of total production of asphalt and total length of motorways and main roads by the same percentage of 13.40; according to the results of the same model for scenario 2 Norway has to increase total production of asphalt by 16.53% and it has to increase the total length of motorways and main roads by 57.27% in scenario 3, in order to reach efficiency level in each situation. A further research is required to know the reason behind the lack of asphalt efficiency performance in Norway.
  - The potential improvement values for inefficient DMUs were generally in the form of a decrease in the input variable x1 (number of companies in asphalt industry- production and laying) and an increase of the output variable y2 (total length of motorways and main roads).
  - Netherlands was the reference country for the most inefficient countries. For that reason, we recommend the inefficient countries to learn, follow and adjust the asphalt pavement applications in Netherlands.

- **Results discussion regarding cost efficiency analysis:**
  - According to efficiency scores results of using (CCR and BCC) model that were used in calculating cost efficiency ratios, Slovenia was in the top ranking by having the least increase in cost in the three scenarios.
  - In scenario 1 and 2, Turkey according to (CCR) model results and France according to (BCC) model results have the highest increases in cost which led Turkey to be in the bottom of the list of cost efficiency analysis by using (CCR) model and France to be in the bottom of the list when (BCC) model is used in measuring cost efficiency. According to scenario 3, France has the highest increase in cost in the both models of (CCR and BCC).
  - According to (BCC) model results of scenario 1 and 2, Turkey was considered a cost efficient, but in scenario 3 was not considered a cost efficient.

With only one research using DEA to evaluate the efficiency of warm mix asphalt mixtures (Li et al, 2013) and without the existence of any literature discussing and evaluating the cost efficiency of asphalt pavements applications, the two methods of analysis performed in this chapter provide a new way of thinking about asphalt pavement applications. Since, most of researches done in this area used DEA to evaluate the local asphalt maintenance protocols and lots of them concentrated on specialized and more practical perspectives of the asphalt and asphalt mixtures, in this chapter we aimed to use an evolutionary perspective to measure the performance of already implemented asphalt pavement policies and according to actual country's data of 2016. We think this chapter will have a huge contribution on literature since it provides a new model of evaluating asphalt pavement applications. We believed it will be the first research measuring the efficiency and cost efficiency of asphalt pavement applications according to different homogenous countries.

In this chapter, we were be able to measure asphalt efficiency and cost efficiency for different scenarios of input and output variables. The limitation of using DEA in measuring efficiency is that it does not give us a ranking for efficient DMUs and a ranking for variables used in measuring efficiency. In the next chapter, we will rank the efficient and cost efficient DMUs and variables by using Grey Relational Analysis.

CHAPTER 4

ASPHALT EFFICIENCY AND COST EFFICIENCY RANKING FOR COUNTRIES AND VARIABLES

4.1. INTRODUCTION

In chapter 3, we analysed the efficiency and cost efficiency of asphalt pavement application for Turkey and the EU countries. For inefficient countries, we calculated the potential improvement values. For efficient countries, we preferred to rank the efficient and cost-efficient countries and variables by using Grey Relational Analysis. Hence, this chapter can be considered as a further analysis to rank the efficient and cost-efficient DMUs and variables. The analysis of this chapter depends totally on the analysis results of previous chapter.

Ranking countries according to efficiency grade might give us a clue about country's position regarding efficiency. If a country ranked as first, there will be a tendency toward knowing its policies and procedures. In which, it will not just be a reference for other countries which have low ranking but also it might be a good reference for inefficient countries.

On the other hand, ranking variables according to degrees of importance is considered worthwhile. Knowing which variable was more important than other is a crucial. In which, when we start to analyse any subject, we cannot judge whether this variable or criteria is important or not.

Grey relational analysis can be considered as the best method to rank entities (i.e. countries, companies, etc) according to different criteria (i.e. variables) or vice versa. GRA defines the relationship between entities and criteria by calculating coefficients.

In asphalt pavement applications, research scholars have used GRA for different purposes related to asphalt pavement. For example, they used it to evaluate the relationship between asphalt mixture types and temperature also they used it to select the best asphalt mixture design according to different criteria.

This chapter provides insight into the ranking process of efficient and cost-efficient countries and variables according to asphalt pavement applications.

4.2. LITERATURE REVIEW

To achieve many of researches objectives regarding country ranking, Grey relational analysis method was used in different fields of interest. Here, we would like to present some of those researches. Yildirim et al (2015) study aimed to evaluate the economic performance of Latin American and Caribbean countries during 2003-2013 periods. 13 countries namely Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Mexico, Panama, Peru, Uruguay, Venezuela with highest GDP hold a position of importance in the Region. They used Grey Relational Analysis for the outranking of countries by using macroeconomic indicators including total investment, gross national savings, inflation, average consumer prices, volume of imports of goods and services, volume of exports of goods and services, unemployment rate, general government revenue, general government total expenditure, general government gross debt, current account balance, gross product domestic (constant). Also, they converted the annual macroeconomic indicators to single data set by using arithmetic mean and weighted arithmetic mean (to be focused on recent years). This combined data was also used for another economic performance evaluation. The results of the empirical analyses showed that Mexico and Dominican Republic ranked as first and second.

Lin and Huang (2009) study aimed to apply Grey Relational Analysis (GRA) and sensitivity analysis to evaluate the tourism competitive potential and to identify and analyse the essential criteria of tourism competitiveness in Asian countries. The results showed that GRA can effectively perform the evaluation of tourism competitiveness of Asian countries and sensitivity analysis express that any changes in the base quantifier might had structural effect on the results.

On the other hand, in asphalt and asphalt pavement applications field research scholars had a tendency toward using Grey Relational analysis method in analysing the performance of asphalt materials and mixtures. Also, most of researches done in this area were conducted in china. In this section, we gave a brief summary about researches done in this asphalt field by using Grey Relational Analysis. Yu et al (2017) study presented and demonstrated a methodology for evaluating a micro-surfacing treatment on asphalt pavement based on the grey system model and grey relational degree theory. Firstly, they analysed over 5,375,000 data points from the Guangdong Province are collected and processed using the Pauta criterion and short-term trends of selected performance indicators including pavement surface condition index (PCI), riding quality index (RQI), rut depth index (RDI), and skid resistance index (SRI). Grey models of different types of indicators were then established for predicting long-term performance. They developed a new PQI model was by using the optimum predicted long-term performance with the application of the grey rational degree theory. Finally, they determined the service life of the micro-surfacing treatment by using the new PQI model. Results demonstrated a representative service life over 4.5 years for the micro-surfacing treatment with a critical PQI value of 80. The proposed methodology validated the micro-surfacing treatment as a valuable assessment system that can be successfully applied with or without other pavement maintenance treatments.

Cheng et al (2016) study aimed to investigate the relationship between properties of fillers and performances of asphalt mastic, four fillers including limestone, hydrated lime, fly-ash and diatomite were selected to prepare corresponding asphalt mastics. They tested the density, specific surface area, particle size distribution, mineralogy component and hydrophilic coefficient of fillers and softening point, viscosity, force ductility and dynamic rheological property of asphalt mastics with different fillers. They employed Grey relational analysis (GRA) method to determine the correlation degree between properties of fillers and high/medium temperature performances of asphalt mastics. Results showed that four fillers presented differences in density, specific surface area, mineralogy component and hydrophilic coefficient. Besides, softening point, viscosity, deformation energy and complex modulus of diatomite asphalt mastic were higher than that of other three filler-asphalt systems. Furthermore, they suggested specific surface area to be the most influential property on the high and medium temperature performances of asphalt mastic in comparison with other properties based on the results of GRA.

Sun et al (2014) aimed to do the grey relational analysis of different semi-rigid pavement structure models fatigue properties based on the grey system theory to gain the key influence parameter on semi-rigid pavement structure fatigue performance.

The research conclusion had a certain instruction function to design pavement structure with excellent anti-fatigue performance.

Tu et al (2014) applied GRA to study coarse grading by combining the characteristics of asphalt mixture. They evaluated, the high temperature stability, low temperature cracking resistance and water stability of asphalt mixture with different grading. The results showed that OGFC-25 gradation apply to asphalt mixture that demands high temperature stability. Similarly, ATB-25 gradation benefits low temperature performance and SUP-25 benefit water stability.

Zhang et al (2014) study objective was to explore performance and economic benefits of the most commonly used fiber asphalt mixture, by studying four types of fiber asphalt mixture through a series of capability tests, such as water stability, high stability, low temperature crack resistance and fatigue stability test. Based on dynamic stability, low temperature bending strain, freeze-thaw splitting strength ratio, fatigue life and cost per square meter as the evaluation index. They proposed to used Grey Relational Analysis (GRA) in this study to determine the best performance and economic benefits of fiber asphalt mixture. The results showed that Fiber B asphalt mixture only had better anti-cracking performance in low temperature and fatigue life, but fiber C asphalt mixture had better performance and economy than the other three fiber asphalt mixtures under the same conditions with grey relational analysis.

Feng and Han (2012) study aimed to use Grey Relation Analysis to perform a thorough analysis of the affective factors on the high temperature behaviour of the coloured asphalt mixture. The result of this analysis showed that the affective factors can be classified as the softening point of coloured asphalt and the aggregate ratio of mixture. They concluded that their research findings will provide a beneficial reference for the design of coloured asphalt mixture.

Du and Kuo (2011) study discussed an algorithm of the grey relational-regression analysis (GRRA) for Hot Mix Asphalt (HMA). They introduced the concept of GRRA based on grey system theory and polynomial regression and they were also be able to derive an equation. They tested examples of the asphalt mixture for comparison to identify the analysis algorithm. The results showed that this algorithm was very effective. Also, they suggested that the algorithm of GRRA can be considered as an alternative to HMA design analysis.

Chang et al (2000) aimed to present the grey theory method in pavement material analysis. First, they based on the characteristic of pavement material, to find the influence factor in pavement material. Second, they used the grey relational grade and GM Model in grey theory to build up an evaluation model to analyze the effect of pavement material in road quality. Finally, they gave an example to implement their method in the preference evaluation on pavement material in road quality.

As a result of literature scanning, it can be said that ranking the efficient and cost-efficient countries and variables did not grab the attention of research scholars. Yet, this analysis results of this chapter might be thought as a reference for upcoming studies in this area.

4.3. RESEARCH OBJECTIVE

The aim of this chapter is to rank the efficient and cost efficient DMUs according to analysis results in chapter 3 by using Grey Relational Analysis. Also, to rank the efficient and cost-efficient variables by defining the degree of importance for each variable according to three scenarios suggested and analysed in chapter 3.

4.4. METHODOLOGY

Grey System (GS) is the system of which part information is known and part information is unknown. Up to now, GS theory has been developing a set of theories and techniques including grey mathematics, Grey relational analysis, grey modelling, grey clustering, grey forecasting, grey decision making, grey programming and grey control, and has been applied successfully in many engineering and managerial fields such as industry, ecology, meteorology, geography, earthquake, hydrology, medicine and military (Ziliang and Siling, 2004; Sallehuddin et al, 2008)

Deng (1989) indicates that the Grey System Theory was initiated in 1982 (as it refers to Deng, 1982), by concerning the incompleteness, uncertainty, and poverty in information. Grey relations, grey elements, grey numbers have been developed to explain the behaviour of a mechanism, economy, even a human body. Deng (1989) also emphasizes that the goal of such as system is to build a bridge between social science and natural science by generating a mathematical modelling framework in order to perform quantitative analysis by considering uncertainty in information (Özdağoğlu et el, 2017).

The essential thought of grey relational analysis (GRA) is to find a grey incidence order, which can be used to describe the relation between the related factors based on data series. The GRA uses information from the grey system to dynamically compare each factor quantitatively. This approach is based on the level of similarity and variability among all factors to establish their relation. The relational analysis suggests how to make prediction and decision, and generate reports that make suggestions. So the GRA can be used to select the independent variables closely related to dependent variables after selecting independent variables based on qualitative analysis and experiences. When the predictive factors are defined, it is easy to create the regression model (Guoqing et al, 2011).

Ranking and compare the alternatives with Grey Relational Analysis can best be treated under 6 steps (Wu 2002; Yildirim et al, 2015):

- Preparing data set and construct decision matrix,
- Constructing reference series and compare matrix,
- Normalization process and constructing normalization matrix,
- Constructing absolute values table,
- Calculating the grey relational coefficient $\xi_i(k)$,
- Calculating the grey relational grade.

Step 1: Preparing data set and construct decision matrix

Suppose there are m pieces of alternative, each alternative has n pieces of evaluating criteria. Sign the alternative as row subscript i, while sign the evaluating criterion as column subscript k,

$$x_i = \big(x_i(k), \dots, x_i(n)\big), \qquad i = 1,2, \dots, m, \quad k = 1,2, \dots, n \qquad 4.1$$

then build the initial decision matrix. $x_i(k)$ is the entity in the ith data sequence corresponding to the kth criterion

4.2

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \dots & x_1(n) \\ x_2(1) & x_2(2) & \dots & x_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m(1) & x_m(2) & \dots & x_m(n) \end{bmatrix}$$

Step 2: Constructing reference series and compare matrix

The reference series which uses for comparing alternatives is,

$$x_0 = \left(x_0(k), \dots, x_0(n)\right), \qquad k = 1,2, \dots, n \qquad 4.3$$

Reference series get from the best indicator of alternative from normalization matrix. On Equation (4.3) $x_0(k)$ presents for beneficial indicator. Then, reference series add to decision matrix and transform to compare matrix.

Step 3: Normalization process and constructing normalization matrix

The variables must be normalized to scale values into an acceptable range. If the variable is to minimize then smaller-is-better characteristic is intended for normalization to scale into an acceptable range by using the following formula (Panda et al,2016);

$$x_i^*(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \qquad 4.4$$

Where, i = 1,...., m; k = 1,..., n, m is the number of efficient countries, n is the number of variables. $x_i(k)$ denotes the original sequence, $x_i^*(k)$ denotes the sequence after data pre-processing, $\max x_i(k)$ denotes the largest value of $x_i(k)$, $\min x_i(k)$ denotes the smallest value of $x_i(k)$, and x is the desired value (Tosun and Phihitili, 2010; Panda et al, 2016)

If the variable is to maximize then bigger-is-better characteristic is intended according to following formula:

$$x_i^*(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)}$$

4.5

After normalization process, the decision matrix transforms to normalization matrix and symbolized with X^*(Yildirim et al, 2015).

$$X^* = \begin{bmatrix} x_1{}^*(1) & x_1{}^*(2) & \dots & x_1{}^*(n) \\ x_2{}^*(1) & x_2{}^*(2) & \dots & x_2{}^*(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m{}^*(1) & x_m{}^*(2) & \dots & x_m{}^*(n) \end{bmatrix} \quad 4.6$$

Step 4: Constructing absolute values table

We can constructing absolute values table by using this formula (Panda et al, 2016).

$$\Delta_{0i} = ||x_0(k) - x_i(k)|| \quad 4.7$$

Where Δ_{0i} is the deviation sequence of the reference sequence and the comparability sequence. $x_0(k)$ implies the reference sequence and $x_i(k)$ termed as comparability sequence.

Step 5. Calculating the grey relational coefficient $\xi_i(k)$

we can calculate Grey relational coefficient $\xi_i(k)$ by using the following formula (Panda et al, 2016):

$$\xi_i(k) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(k) + \xi\Delta_{max}} \quad 4.8$$

Where Δ_{0i} is the deviation sequence of the reference sequence and the comparability sequence (calculated in step4). Δ_{min} and Δ_{max} are the minimum and maximum values of the absolute differences (Δ_{0i}) of all comparing sequences. ξ is distinguishing or identifaction coefficient and the range is between 0 to 1. Usually, the value of ξ is taken as 0.5.

Step 6. Calculating the grey relational grade

The Grey relational grade (GRG) can be found as follows (Panda et al, 2016):

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\xi_i(k) \quad 4.9$$

Where γ_i is the required grey relational grade for ith country and $n =$ number of variables in our case.

4.5. THE ASPHALT EFFICIENCY AND COST EFFICIENCY RANKING BY USING GREY RELATIONAL ANALYSIS (GRA)

In this section, we ranked efficient and cost efficient DMUs and we defined the degree of importance of each variable used in analysing the three scenarios and in analysing cost efficiency for DMUs by using Microsoft Excel 2007.

At first, we performed a Grey Relational Analysis method to rank efficient DMUs and variables. Then, we used same method to rank cost efficient DMUs and variables.

We presented the analysis results of ranking efficient DMUs and variables in section 5.1. Section 5.2 on the other hand, shows the analysis results of ranking cost efficient DMUs and variables.

4.5.1. Efficiency Ranking for Countries and Variables for Scenario 1, 2 & 3

In chapter 3 section 5.1, we presented the analysis results for three different scenarios by using two models of DEA (CCR & BCC). The analysis of this section depends totally on the efficiency analysis results obtained in section chapter 3 section 5.1. So to rank the efficient DMUs and variables in each scenario, we used Grey Relational analysis. To perform GRA, we preferred to consider the efficient DMUs of (BCC) model.

4.5.1.1. Efficiency Ranking for Countries

In order to perform GRA to rank efficient countries, we need to recall the steps shown in section 4. To clearly show how did we perform GRA, we explained each step in details:

Step 1: values normalization

The variables must be normalized to scale values into an acceptable range. If the variable is to minimize then smaller-is-better characteristic is intended for normalization to scale into an acceptable range by using the following formula (Panda et al,2016);

$$x_i^*(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)}$$

Where, i = 1,...., m; k = 1,..., n, m is the number of efficient countries, n is the number of variables. $x_i(k)$ denotes the original sequence, $x_i^*(k)$ denotes the sequence after data pre-processing, $\max x_i(k)$ denotes the largest value of $x_i(k)$, $\min x_i(k)$ denotes the smallest value of $x_i(k)$, and x is the desired value (Tosun and Phihitili, 2010; Panda et al, 2016)

If the variable is to maximize then bigger-is-better characteristic is intended according to following formula:

$$x_i^*(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)}$$

Now according to step 1, we can present our results from following this step for the three scenarios. Table 4.1 shows the results of data normalization for each scenario.

Table 4.1: Data Normalization Results For Three Scenarios

Countries	**Scenarios**									
	Scenario 1				**Scenario 2**			**Scenario 3**		
	x1 (min)	**x2 (min)**	**y1 (max)**	**y2 (max)**	**x1 (min)**	**x2 (min)**	**y1 (max)**	**x1 (min)**	**x2 (min)**	**y2 (max)**
Ideal Sequence	1	1	1	1	1	1	1	1	1	1
France	0.910	0.151	0.825	0.150	0.910	0.151	0.825			
Great Britain	0.945	0.574	0.526	1.000	0.945	0.574	0.526	0.862	0.000	1.000
Netherlands	0.952	0.926	0.170	0.021	0.952	0.926	0.170			
Slovakia	1.000	0.993	0.008	0.000	1.000	0.993	0.008	1.000	0.984	0.000
Slovenia	0.965	1.000	0.000	0.039	0.965	1.000	0.000	0.911	1.000	0.039
Spain	0.603	0.818	0.296	0.537	0.603	0.818	0.296	0.000	0.572	0.537
Turkey	0.000	0.000	1.000	0.604	0.000	0.000	1.000			

Step 2: calculating Grey relational coefficient $\xi_i(k)$

By using normalized values found in step 1, we can calculate Grey relational coefficient $\xi_i(k)$ by using the following formula:

$$\xi_i(k) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(k) + \xi\Delta_{max}}$$

Where Δ_{0i} is the deviation sequence of the reference sequence and the comparability sequence, $\Delta_{0i} = ||x_0(k) - x_i(k)||$

Where $x_0(k)$ implies the reference sequence and $x_i(k)$ termed as comparability sequence. Δ_{min} and Δ_{max} are the minimum and maximum values of the absolute differences (Δ_{0i}) of all comparing sequences. ξ is distinguishing or identifaction coefficient and the range is between 0 to 1. Usually, the value of ξ is taken as 0.5.

Now by implementing step 2 in our normalized values, we gained Grey relational coefficient as shown in Table 4.2. Table 4.2 shows the values of Grey relational coefficient.

Table 4.2: Grey Relational Coefficient Values

Countries	**Scenarios**									
	Scenario 1				**Scenario 2**			**Scenario 3**		
	x1	**x2**	**y1**	**y2**	**x1**	**x2**	**y1**	**x1**	**x2**	**y2**
France	0.847	0.371	0.740	0.370	0.847	0.371	0.740			
Great Britain	0.901	0.540	0.513	1.000	0.901	0.540	0.513	0.783	0.333	1.000
Netherlands	0.912	0.872	0.376	0.338	0.912	0.872	0.376			
Slovakia	1.000	0.986	0.335	0.333	1.000	0.986	0.335	1.000	0.968	0.333
Slovenia	0.934	1.000	0.333	0.342	0.934	1.000	0.333	0.848	1.000	0.342
Spain	0.558	0.733	0.415	0.519	0.558	0.733	0.415	0.333	0.539	0.519
Turkey	0.333	0.333	1.000	0.558	0.333	0.333	1.000			

Step 3: calculating the Grey relational grade

The Grey relational grade (GRG) can be found as follow:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\xi_i(k)$$

Where γ_i is the required grey relational grade for ith country and $n =$ number of variables.

By following step 3, we can find the Grey relational grade (GRG) for each country and then we can rank them according to their grades (Table 4.3). Which is the last step in ranking efficient DMUs. Table 4.3shows Grey relational grade and ranking for each country according to three scenarios.

Table 4.3: Grey Relational Grade (GRG) and Ranking for Each Country According To Three Scenario

Countries	Scenarios					
	Scenario 1		Scenario 2		Scenario 3	
	GRG	Ranking	GRG	Ranking	GRG	Ranking
France	0.582	5	0.653	4		
Great Britain	0.739	1	0.651	5	0.706	3
Netherlands	0.624	4	0.720	3		
Slovakia	0.664	2	0.774	1	0.767	1
Slovenia	0.652	3	0.756	2	0.730	2
Spain	0.556	6	0.569	6	0.464	4
Turkey	0.556	7	0.556	7		

From Table 4.3, we can notice that according to scenario 1 Great Britain has the highest value of grey relational grade which made it in the top ranking. According to scenario 2 and scenario 3, Slovakia has the highest value of Grey relational grade which ranked to be number 1 in the both scenarios. On the other hand, Turkey has the lowest values of Grey relational grade in scenario 1 and 2 which made it in the bottom of the ranking list.

4.5.1.2. Efficiency Ranking for Variables

After we ranked the efficient country by calculating grey relational grade for each efficient country and obtained analysis results. It is also worthwhile to consider ranking variables used in each scenario to define the degree of importance for each one of them. In order to do so, for each variable; we divided the sum of grey relational coefficients by number of efficient countries in each scenario. Table 4.4 shows the Grey relational grade and ranking for each variable.

Table 4.4: Grey Relational Grade (GRG) and Ranking for Variables According to Three Scenarios

Countries	Scenarios					
	Scenario 1		Scenario 2		Scenario 3	
	GRG	Ranking	GRG	Ranking	GRG	Ranking
x1	0.784	1	0.784	1	0.741	1
x2	0.691	2	0.663	2	0.710	2
y1	0.073	4	0.534	3		
y2	0.494	3			0.549	3

According to Table 4.4, x1 in the three scenarios has the highest value of Grey relational grade which makes it in the first degree of importance. x2 has the second degree of importance. Whereas, y1 has the last degree of importance in scenario 1 and 2.

4.5.2. Cost Efficiency Ranking for Countries and Variables for Scenario 1, 2 & 3

The aim of this section was to rank cost efficiency countries and variables by using Grey Relational analysis. So in order to achieve this section aim, we needed to recall cost efficiency analysis results done in chapter 3 section 5.2 to perform our analysis.

4.5.2.1. Cost Efficiency Ranking for Countries

In this section and by following the same steps done in this chapter section 5.1, we will rank cost efficient countries for each scenario after that, we will define the degrees of importance for each variable.

Here and by following the same steps presented in section 5.1, we gathered the results of grey relational coefficient, grade values and ranking in one table to avoid repeating. Table 4.5 shows the grey relational coefficients along with grey relational grade and ranking for each cost-efficient country in each scenario.

Table 4.5: Grey Relational Coefficient and Grey Relational Grade Values for Cost Efficient DMUs According to Three Scenarios

Countries	Scenario 1							
	x1 (min)*	**x2 (min)***	**y1 (max)***	**y2 (max)***	**RIIS (min)***	**RIMS (min)***	**GRG**	**ranking**
Netherlands	0.912	0.872	0.376	0.341	0.333	0.548	0.564	4
Slovakia	1.000	0.986	0.335	0.333	0.854	0.952	0.743	2
Slovenia	0.934	1.000	0.333	0.348	1.000	1.000	0.769	1
Spain	0.558	0.733	0.415	0.818	0.498	0.333	0.559	5
Turkey	0.333	0.333	1.000	1.000	0.345	0.943	0.659	3
	Scenario 2							
Countries	**x1 (min)***	**x2 (min)***	**y1 (max)***	**RIIS (min)***	**RIMS (min)***	**GRG**	**ranking**	
Norway	0.934	0.826	0.369	0.521	0.465	0.623	3	
Slovakia	1.000	0.986	0.335	0.847	0.952	0.824	2	
Slovenia	0.934	1.000	0.333	1.000	1.000	0.853	1	
Spain	0.558	0.733	0.415	0.486	0.333	0.505	5	
Turkey	0.333	0.333	1.000	0.333	0.943	0.589	4	
	Scenario 3							
countries	**x1 (min)***	**x2 (min)***	**y2 (max)***	**RIIS (min)***	**RIMS (min)***	**GRG**	**ranking**	
Great Britain	0.783	0.333	1.000	0.333	0.393	0.569	4	
Norway	0.848	0.669	0.367	0.560	0.465	0.582	3	
Slovakia	1.000	0.968	0.333	0.867	0.952	0.824	2	
Slovenia	0.848	1.000	0.342	1.000	1.000	0.838	1	
Spain	0.333	0.539	0.519	0.525	0.333	0.450	5	

*data were normalized according to min (smaller-the-better), max (bigger-the-better)

From Table 4.5, it can be notice that Slovenia has the highest grey relational grade according to three scenarios which made it in the top list of cost-efficient countries. According to three scenarios as well, Slovakia came in the second order, whereas Spain came in the last order.

4.5.2.2. Cost Efficiency Ranking for Variables

This section covers the analysis results of cost efficiency ranking for variables. we presented the results of ranking variables according to three scenarios in Table 4.6. Hence, Table 4.6 shows the Grey relational grade and ranking results for each variable.

Table 4.6: Grey Relational Grade (GRG) and Ranking for Variables According to Three Scenarios

Countries	Scenarios					
	Scenario 1		Scenario 2		Scenario 3	
	GRG	Ranking	GRG	Ranking	GRG	Ranking
x1	0.747	3	0.752	2	0.763	1
x2	0.785	1	0.776	1	0.702	2
y1	0.492	6	0.491	5		
y2	0.568	5			0.512	5
RIIS	0.606	4	0.637	4	0.657	3
RIMS	0.755	2	0.739	3	0.629	4

From Table 4.6, according to scenario 1 and 2; x2 has the highest value of GRG which indicates that it has a superior degree of importance, whereas y1 has the least degree of importance. In scenario 3 x1 has the superior degree of importance where as y2 has the least degree of importance.

4.6. RESULTS AND DISCUSSION

The aim of this chapter was to rank efficient and cost efficient DMUs and variables according to asphalt pavement application. We implemented Grey Relational Analysis method to achieve this chapter objectives. We can summarize the analysis results as follows:

- The results of efficiency ranking for countries showed that; according to scenario 1, Great Britain and Slovakia were ranked as first and second; according to scenario 2 and 3, Slovakia and Slovenia were ranked as first and second.
- The results of efficiency ranking for countries also showed that; according to scenario 1 and 2, Turkey was ranked as seventh which is the least ranking. The same result is valid for cost efficiency analysis done in chapter 3. We recommend Turkey to review and enhance the implemented cost policies.
- The results of efficiency ranking for variables showed that: according to three scenarios, Number of companies in asphalt industry - production and laying (x1) was ranked as first which indicates that it was the most

important variable. Point the fact that, it was also the most recommended input variable to be reduced for inefficient countries to be efficient according to potential improvement values results of chapter 3. Hence, we recommend countries to intervene to minimize the number of companies in asphalt industry.

- The results of cost efficiency ranking for countries showed that; according to three scenarios, Slovenia and Slovakia were ranked as first and second. Which is similar to result of cost efficiency ranking done after calculating cost efficiency ratio in chapter 3.
- The results of cost efficiency ranking for variables showed that; according scenario 1 and 2, Total of bitumen consumption (x2) was ranked as first which indicates that it was the most important variable. Whereas in scenario 3, Number of companies in asphalt industry - production and laying (x1) was ranked as first.
- Although the output variable y2 (total length of motorways and main roads) was not the most important variable, it was the most recommended output variable to be increased for inefficient countries to be efficient according to potential improvement values results of chapter 3. Which means that countries like Turkey, France and Norway have a lack in the length of motorways and main roads. Thus, we recommend those countries to increase the length of their motorways and road ways.

Most of previous researches in asphalt field used GRA to evaluate the different characteristics of asphalt and asphalt mixtures. In this chapter, we aimed to use GRA for two reasons; the first reason is to rank the efficient and cost efficient countries as we mentioned earlier to avoid the limitation of DEA done in chapter 3, the second reason is to rank the variables used in analysing the efficiency and cost efficiency according to their degree of importance. We think our contribution to literature will be the use of GRA to conduct a further analysis to rank the efficient and cost efficient DMUs and variables according to asphalt pavement applications.

CONCLUSION

Research study is a pivotal key for country’s economic growth and prosper. Lots of researches done in different field of interest have helped in investigating several phenomimes and in finding reliable and applicable solutions to different types of problems and obstacles.

Recently, the world is having a panic attack after corona virus pandemic spread globally to infect more than 180 countries in a short period of time. Today, many research groups in different countries are racing to find cure and vaccine to corona virus. In business world, we do not face actual viruses but instead we might face several problems and obstacles which just look like a real virus. After the global financial crisis of 2008, the world had a panic attack similar to corona virus’s panic attack. After this incident, the world became well familiar of how financial crisis looks like and it is working diligently to avoid the repetition of such crisis.

Although, there are lots of efforts exhausted to search for solutions for different problems, many times the solution might not be applicable, the data might not be accurate, the analysis techniques might not be suitable and etc. At the end, we find ourselves obligated to do different trails and experience different methods until we reach the most reliable and applicable solution. Note that, the circumstances might change in each trial. Moreover, in each trial we need to plan, organize, lead and control. These four functions of management are crucial for any decision-making process. Especially, decisions regarding resource management.

Resources play an important role in our lives. Recently, the International Monetary Fund (IMF) stated that Gulf Cooperation Council (GCC) states’ financial wealth could be over in 15 years. However, hearing this statement let the (GCC) searching for solutions to avoid the actualization of this incident. The reason behind this statement lays on the fact that the financial wealth of (GCC) is mainly obtained from crude oil revenues. Since, the crude oil prices dropped in 2014 and 2015, The government was under great pressure to generate non-oil revenues and fixed their finances which led (IMF) to make such statement about (GCC) financial wealth.

If we look at the financial wealth case of (GCC), we can notice that they were lucky to be able to predict the crisis before it is actually happened. In other cases, people might not be that lucky. Out of sudden all of their resources might be vanished. That is why, the efficient resource planning and allocation is considered crucial. Point the fact that, the efficiency term goes beyond it is fundamental meaning of doing things well. It is actually give us ideas about how to develop our businesses. Moreover, if we have the ability to avoid wasting of materials, efforts and money, we might protect ourselves from resource extinction. Though, in the real life being efficient is not an easy task to do. Yet, lots of time measuring performance by efficiency gives results help in developing our businesses so it is indispensable technique in a continually evolved world.

As we mentioned in research introduction, we planned our study according to our general objectives and our analysis objectives. The results regarding our general objectives showed that; Turkey is efficient under scenario 1 and 2, when we used (BCC) model of DEA. When we used (CCR) model of DEA, Turkey is not efficient under the three scenarios. Generally according to potential improvement values is recommended to take Netherlands as reference and to maximize the total asphalt production. In cost efficiency analysis, according to (BCC) model results of scenario 1 and 2 Turkey is considered cost efficient but in scenario 3 it is not considered a cost efficient and it has the highest increase in cost that is why we recommend Turkey to have a plan to minimize the cost of road infrastructure. When we ranked the efficient countries, Turkey came in the last order under scenario 1 and 2.

The results of our second general objective lay on our analysis contribution to the literature. First, by using different variables combinations and two kinds of analysis, we were be able to present a new model discussing the results of conducting country's grouping by focusing on asphalt pavement applications on road constructions such a model until the present time had not been discussed in any research. We think this model will have a contribution to the literature and might be considered as a reference for further researches regarding the asphalt pavement applications. Second, With only one research using DEA to evaluate the efficiency of warm mix asphalt mixtures (Li et al, 2013) and without the existence of any literature discussing and evaluating the cost efficiency of asphalt pavements applications, the two methods of analysis performed in this chapter provide a new way of thinking about asphalt pavement applications. Since, most of researches done in this area used DEA to evaluate the local asphalt maintenance protocols and lots of them concentrated on specialized and more practical perspectives of the asphalt and asphalt mixtures, in this chapter we aimed to use an evolutionary perspective to measure the performance of already implemented asphalt pavement policies and according to actual country's data of 2016. We think this chapter will have a huge contribution on literature since it provides a new model of evaluating asphalt pavement applications. We believed it will be the first research measuring the efficiency and cost efficiency of asphalt pavement applications according to different homogenous countries. Third, most of previous researches used GRA to evaluate the different characteristics of asphalt and asphalt mixtures. In this chapter, we aimed to use GRA for two reasons; the first reason is to rank the efficient and cost efficient countries as we mentioned earlier to avoid the limitation of DEA done in chapter 3, the second reason is to rank the variables used in analysing the efficiency and cost efficiency according to their degree of importance. We think our contribution to literature will be the use of GRA to conduct a further analysis to rank the efficient and cost efficient DMUs and variables according to asphalt pavement applications.

In this research, according to asphalt pavement applications for homogenous group of countries, we were be able to analyse the efficiency and cost efficiency for those countries by using different scenarios and presenting the results of ranking the efficient and cost efficient countries and variables (according to their degree of importance), which made our research a hybrid study. We believe that, our research study will contribute to literature and will be a reference for other researches in this field.

In the scope of our analysis objectives, we evaluated the efficiency of asphalt pavement applications for Turkey and some of European Union countries by considering some of inputs and outputs related to asphalt pavements. At first, we clustered Turkey and 16 European countries by using k-mean cluster analysis and Multidimensional scaling analysis. Then, we chose one group (where Turkey involved in) to measure their asphalt pavements performance by using Data Envelopment Analysis (DEA) models of efficiency and according to three different scenarios. After that, we went further to analyse the cost efficiency for the same group. In the last chapter, since DEA models do not provide a rank for the efficient decision-making units (DMUs) according to their degree of importance, we performed a further analysis to rank the efficient and cost efficient DMUs and variables by using Grey Relational

Analysis (GRA). According to analysis results, in general some European countries were efficient and cost efficient regarding the asphalt pavement applications and under the three scenarios suggested such as Slovenia. Unfortunately, other countries suffer from the inefficiency of asphalt pavement applications under the three scenarios suggested such as Norway.

Doing the above-mentioned evaluations are generally done according to engineering criteria. According to this evaluations results and the perspective of asphalt expert, we can conclude the following:

- Generally, according to surface measurement, it is ideally defined that countries with a small surface area, less business volume and very less companies number in asphalt industry are more efficient and cost efficient.
- In such countries, both road constructions and maintenance activities are considered to be cost-efficient as they are seen at a low rate compared to the overall road volume.
- However, in countries that dynamic and at the same time it has a lot of work to do such as Turkey might face some problems. Asphalt road construction in countries such as Turkey maintained by several different institutions, varies according to the needs of the institutions engaged in the field. For example, the municipalities make the roads in the city, the General Directorate of Highways makes the intercity roads, the General Directorate of Forestry makes the inner roads of the forests and the Ministry of Tourism makes the tourist roads. For this reason, the need of the roads changes according to the current conditions. Therefore, Turkey is seen as a steady increase in the rapid development of the road network of the country.
- Likewise, it is not desirable to have too many road companies in the country. Generally, governments have efforts to reduce firms. In road tenders, tender conditions are aggravated so that fewer companies can get jobs. This is an expected result, as previously presented in the results of our research.
- One of the problems experienced in all road constructions is infrastructure investments. If infrastructure is not done properly, maintenance costs increase continuously. The first road constructions must be done carefully, otherwise

these investments never decrease. This situation also emerged in the thesis study. For Turkey, an extensive research is required to solve such issues.

- Infrastructure investments in European countries are less because population growth and development of cities are not like Turkey. Cities were established years ago and population growth remained stable at certain rates. Therefore, there is no physical situation that would require infrastructural investments to increase constantly. In countries like Turkey, because of the constant movement in this situation, the cost efficiency status in the study is not acceptable for infrastructure investments.

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