ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

PRIVATIZATION, LIBERALIZATION AND DEREGULATION OF TURKISH STATE RAILWAYS AND FRAMEWORKS FOR PUBLIC-PRIVATE PARTNERSHIPS

Ph.D. THESIS

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JANUARY 2020

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

TÜRKİYE DEVLET DEMİRYOLLARININ KAMU-ÖZEL İŞBİRLİĞİ KAPSAMINDA ÖZELLEŞTİRİLMESİ VE SERBESTLEŞMESİ

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To my family

FOREWORD

It has been a great privilege to spend almost ten years in the Transportation Engineering Department of Istanbul Technical University during my MSc and PhD studies. There are a number of people without whom this thesis might not have been written, and to whom I am greatly indebted.

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ABBREVIATIONS

ARL : Airport Rail Link
BLT : Build-Lease-Transfer
BOO : Build-Own-Operate
BOOT : Build-Own-Operate-Transfer
BOT : Build-Operate-Transfer
BT : Build-Transfer
CCPPP : Canadian Council for Public-Private Partnerships
CG : Coalitional Game
CTRL : Channel Tunnel Rail Link
DB : Design-Build
DB : Deutsche Bahn
DBF : Design-Build-Finance
DBFM : Design-Build-Finance-Maintain
DBFMO : Design-Build-Finance-Maintain-Operate
DBFO : Design-Build-Finance-Operate
DBOM : Design-Build-Operate-Maintain
DCMF : Design-Construct-Maintain-Finance
EU : European Union
EUMS : European Union Member States
FC^- : Financial Cost Minus
GDP : Gross Domestic Product
HSR : High Speed Rail
IP : Infrastructure Provider
JV : Joint Venture
MC^+ : Marginal Cost Plus
NP : Non-Profitable
NRI : National Railway Institution
NTU : Non-Transferable Utility
MPD : Maputo Development Corridor
OECD : Organisation for Economic Cooperation and Development

O&M **:** Operation & Maintenance
P **:** Profitable
PFI **:** Private Finance Initiative
PPP **:** Public-Private Partnership
PRM **:** Project Risk Management
PSC **:** Public-Sector Comparator
PSL **:** Passenger Satisfaction Level
PTSO **:** Private Train Service Operator
RFP **:** Request for Proposals
RFQ **:** Request for Qualifications
RMA **:** Risk Mitigation Alternative
ROI **:** Return on Investment
RPI **:** Railway Performance Index
SMC **:** Social Marginal Cost
SP **:** Stated Preference
SPV **:** Special Purpose Vehicle
TAC **:** Track Access Charge
TCDD **:** Turkish State Railways
TUCG **:** Transferable Utility Coalition Game
VAT **:** Value-Added Tax
VFM **:** Value for Money
WOC **:** Weight of Cost
WOT **:** Weight of Time

SYMBOLS

$\boldsymbol{\alpha}$	**:** Coefficient of Timing
$\boldsymbol{\beta}$	**:** Coefficient of Ticket Pricing
R	**:** Track Access Rights
$\boldsymbol{S}$	**:** Set of Stations
$\mathbf{T_D}$	**:** Dwell Time at the Station
$\mathbf{T_R}$	**:** Inter-Station Runtime
$\boldsymbol{\omega}$	**:** Rolling Stock Type
$\boldsymbol{\phi}$	**:** Flex Level
$\boldsymbol{\psi}$	**:** Train Time Schedule
$\boldsymbol{\zeta}$	**:** Train Service Arrival at the Station

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PRIVATIZATION, LIBERALIZATION AND DEREGULATION OF TURKISH STATE RAILWAYS AND FRAMEWORKS FOR PUBLIC-PRIVATE PARTNERSHIPS

SUMMARY

In modern societies and in the sense of a holistic view, political, social and economic sustainability deeply depends on the efficient transport systems. From the economic perspective, transport facilities extend markets, provide the capital and labor mobility, enhance the mass production, ensure price stability, create employment opportunities, challenge the monopolies, develop industries and agriculture, and increase national wealth. As for the social dimension, they facilitate the discovery of new lands and redound to the distribution of population, raise the living standards, encourage cultural and idea exchanges amongst the people from all corners of the world, enable people and authorities to manage the national disasters, and broaden the people's outlook. Politically, they maintain national unity, pave the way for integration, boost national independency, strengthen the national defense, and provide national wealth and income in the country. Transport facilities might be categorized in three major groups including: Land (rail, road and pipeline), air and water (shipping).

Indubitably, during the last two centuries rail industry played the pioneering role in the freight and passenger transportation and it was unrivaled for almost a full century. It is no exaggeration to say that the industrialization and globalization process would hobble without rail networks. However, the Post-Second-World-War era was a turning point where highway overtook the rail and the gap began to experience an incessant expanse. However, emerging technologies in the rail sector such as high-speed rail services in some European and Far-Eastern countries triggered the revival of railways in later decades of 20^{th} century. Eventually, due to some critical parameters such as environmental impacts, energy efficiency, safety issues, ability in the transportation of bulky and heavy goods, economic issues, larger capacity, etc. railways have to revive and the coming decades will provide a golden opportunity in realization of the mentioned goal.

In Turkey, the history of railways dates back to the Ottoman age where most of the lines were constructed by the imperialist countries such as England, France and Germany. There is no doubt that all these countries were following their own goals in developing such facilities. However, after the proclamation of the republic in 1923, considerable steps were taken to nationalize the rail network in the country and develop new assets. Similar to the worldwide trend, rail sector experienced a serious retrogress after the Second World War in Turkey and it continued until the beginning of the new millennium. In early 2000s, Turkish government decided to prioritize the investments in transport facilities, particularly in the rail sector and in development of high-speed rail network.

From a historical perspective, in Turkey and many other countries around the globe, all layers of the rail market including but not limited to the track construction, rolling stock provision, service operation and system maintenance were controlled by national monopolies. On one hand, the efficiency of such monopolistic power in the sector was questioned by authorities and researchers unanimously. On the other hand, economic crises and budget limitations acted as barriers in development of new rail lines. These obstacles persuaded the governments to be in search of effective alternatives to the traditional approaches. Within this context, a remarkable remedy was activation of private finance in provision of public infrastructures such as railways. Thus, the term "public-private partnership" (PPP) came into prominence in development of such facilities.

In the Turkish rail sector, PPP approaches are mostly utilized in the framework of Greenfield and Brownfield projects. In the former one, private sector is responsible in the projection and construction phases, too. Build-Operate-Transfer (BOT) is the most common PPP tool in provision of transport facilities in Turkey. A remarkable number of transport facilities in the country has been actualized under BOT/PPP approaches. However, there is no such an application in the rail sector of Turkey to the date. As for the Brownfield approach, private sector is mostly responsible for the enhancement and better operation of the existing systems to make profit in return for the payment to the public entity. In provision of high-speed rail (HSR) network and new conventional lines in the country beside the improvement of the existing systems, both Greenfield and Brownfield approaches can be vastly used and a comprehensive evaluation and analysis of the process is required to reach successful outcomes. In Literature, there are numerous researches in favor and in opposition to the application of PPPs in infrastructure projects and in this thesis, it is targeted to make such a fair and comprehensive analysis.

As is clear, railways are multi-disciplinary, multi-decision-making agents with conflicting interest groups. Rail PPPs involve three major interest groups including: public entity as the provider of the infrastructure, private firms as the rail service operators and passengers as the users. These groups follow some contradicting views. Passengers look for the services which are compatible with their budget and timing preferences. They naturally prefer to pay less for the service. On the other hand, private service operators tend to maximize their ticket prices to obtain highest possible level of revenues. Private firms also tend to pay less as Track Access Charge (TAC) to the public entity. However, public side tries to collect more TAC values from the private operators and it also urges the private firms to keep the prices in a limited level to make the passengers feel satisfied. Consequently, there are profound conflicts amongst the players of the system.

Optimization methods and tools are very useful in evaluation of such environments. However, conventional optimization methods fail to satisfy the realism since they simplify the multi-agent and multi-objective environment to one in which all interest groups follow a unique system-wide objective. Indeed, in such settings in real world, each group pursue its own individualistic goals and tend to maximize its own benefit without regard to the thoughts of other players. At this point, a need for a more realistic optimization and simulation method is highly necessitated. "Game Theory" can provide such a philosophy and tool to evaluate the rail market liberalization in a realistic manner. Thus, in this thesis we have used game theory in two fields. In the first case, behavior modeling and conflict resolution is addressed by some simple 2×2 games entitled: "Prisoner Dilemma", "Chicken" and "Stag-Hunt" games.

Afterwards, a liberalized rail line analysis is done using cooperative game with non-transferable utility approach. To actualize the simulation, “GoLang” programming language has been used in this thesis to evaluate the network inspired by the Istanbul-Ankara HSR. The data for passengers has been collected via conducting a stated preference (SP) survey at the Pendik station in Istanbul.

Game theoretic behavioral analysis of the conflicting agents prove that the early understanding of the probable problems may avoid serious contradictions in the dynamic process of long-term rail PPPs. In addition, the results proposed by the model used in this thesis provide better resolutions for all interest groups by application of various time scheduling

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ÖZET

Bir ülkenin ekonomik kalkınma ve gelişmişlik seviyesinin önde gelen gösterge ve etkenlerinden bir tanesi, o ülkenin ulaşım ağlarıdır. Çağdaş bir toplumda, ekonomik, sosyal ve siyasi istikrar ve sürdürülebilirlik, o toplumdaki güçlü ulaşım ağları ile ciddi derecede etkileşimdedir. Ulaşım ağlarının ekonomik boyuttan ele alınmasında, piyasaların genişlemesi, iş gücü ve sermayenin aktarılması, toplu üretime sunduğu fırsatlar, iş imkanları yaratmak, tekelde olmaya etkili bir düzeyde karşı gelmek, tarım ve sanayi ürünlerinin üretimi ve dağıtımın, ve milli gelirin artımın göze çarpan etkilerden sayılabilir. Sosyal açıdan konuyu irdelemeye gelince, ulaşım imkanlarının yeni toprakların keşfi, nüfus yoğunluğu ve dağılımının daha etkili olması, insanların yaşam kalitelerinin yükselmesi, insanların dünyanın dört bir yanından birbirleri ile kültürel ve fikir paylaşımlarının yapılması, doğal afetlerde hızlı ve güvenli bir biçimde müdahalelerin yapılması, ve insanların ufkunun genişlemesinde payı pahabiçilmezdir. Siyasi bakımdan, ülkelerin ulaşım ağları ve imkanları ülkedeki ulusal birliğin hayata geçmesinde, bütünleştirici siyasetlerin uygulanmasında, ulusal bağımsızlığa sahip çıkılmasında, milli savunma konusunda başarılı olmakta, ve devlet ve milleti yönetmek için ulusal refah ve gelir kaynaklarının yaratılmasında büyük rolü vardır. Ulaşım demiryolu, karayolu, havayolu, denizyolu ve boruhattı sektöerlerinden oluşmaktadırç her sektörün kendi içinde alt sistemleri ve etki alanları vardır.

Hiç şüphesiz, 19. yüzyılın başlarından beri, demiryolu sektörü hem yolcu hem de yük taşımacılığında yeni bir çağ açarak, dünya tarihinde küresel olarak ulaşımı daha etkili hale getirdi ve bu konuda öncülük yaptı. Hemen hemen tam bir asır öncülüğünü rakipsiz bir şekilde devam ettiren demiryolları, 2. Dünya Savaşı sonrası yerini sürekli bir şekilde karayollarına vermeye başladı. Bütün bilim adamları, araştırmacıların ve siyasilerin sözbirliğiyle demiryollarının sanayileşme ve küreselleşmenin olmazsa olmazı olduğunu kabul ettikleri demiryolu sektörü artık eski gücünü yitirmiştir. Dünyada artık her geçen gün yük ve yolcu taşımacılığında demiryollarının payı giderek düşüyordu. Bu düşüş onyıllarca devam ederken, 20. yüzyılın son çeyreğinde bazı Batı Avrupa ve Uzak Doğu ülkelerindeki demiryolu sektöründe geliştirdikleri yenilikçi telnolojiler (yüksek hızlı demiryolları gibi), gidişatın terse dönmesi ve demiryollarının tekrar ıvmeli bir şekilde değer kazanmasına yol açtı. Sonuç olarak, demiryollarının daha çevreci olmasına, enerji verimliliğinin yüksek olmasına, daha güvenli olmasına, ağır ve hacimli yüklerin taşınmasında daha etkili olmasına, kapasitesinin fazla olmasına vs gibi konulara istinaden, demiryollarının önümüzdeki yıllarda dünyada daha da etkili hale gelmesi düşünülüyor.

Türkiyede demiryollarının tarihi çok eski zamanlara ve Osmanlı İmparatorluğuna dönmektedir. 1800lı yıllarda Osmanlı topraklarında yapılan çoğu demiryolu projesi, İngilizler, Fransızlar ve Almanlar tarafından yapılmıştır. İsmi geçen yabancı

ülkelerin Türkiyede yapmış oldukları demiryolları açıkca kendi siyasi, askeri ve iktisadi amaçlarına hizmete dayanarak yapılmıştır ve yerel halka ve ekonomiye hitap etmesi pek düşünülemez. Bu süreç, Türkiye Cumhuriyetinin ilanına müteakiben, ulusal çıkarlara paral olacak bir şekilde yön değiştirmiştir. Osmanlıdan günümüz Türkiyesinin topraklarında kalan demiryolları millileştirilme sürecine gitmiştir ve azimli bir şekilde altyapı ve hatlarının geliştirilmesine gayret gösterilmiştir. Fakat bütün dünyada olduğu gibi, 2. Dünya Savaşı sonrası, Türkiyede de karayolları artık daha etkili bir ulaşım moduna dönüşmüştür ve giderek demiryolları yük ve yolcu taşımacılığında ciddi bir şekilde değer kaybına uğramıştır. En son aşamada, 2000li yılların başında, devletin ulaşım politikalarına ciddi önem vermesi sayesinde bütün modlarda özellikle demiryollarında canlandırma siyasetleri yaşanmıştır. Bu kapsamda, ülkenin yüksek hızlı demiryolu ağının hızlı bir şekilde geliştirilmesi, yeni konvansyonel hatların yapılması ve mevcut altyapıyı iyileştirilmesi devletin en başta gelen amaçlarından olmuştur.

Hemen hemen bütün dünyada olduğu gibi, uzun yıllar boyunca Türkiyede de demiryolu sektörünün projelendirme, hat yapım ve inşaatı, taşıt tedariki, işletme ve bakım onarım gibi bütün alt sektörleri devlet tekelinde olmuştur. Bir taraftan, tekelde yürütülen yönetimin hemen hemen her alanda ve sektörde yetersiz ve etkisiz olduğu karar vericiler ve araştırmacılar tarafından onaylanmıştır. Diğer yandan, dünyada zaman zaman yaşanan ekonomik krizler, bir çok ülkenin demiryolu gibi büyük sermaye gerektiren altyapılara yatırım yapmasın önünde ciddi engeller oluşturmuştur. Bu nedenler ile, artık bu gibi yatırım ve kamu yararı olan hizmetlerde daha etkili yöntemler araştırılmıştır. Böylece, bü yöntemlerin neredeyse başında gelen özel sektörün sermaye ve çok-yönlü deneyim katılımı ortaya çıkmıştır. Böylelikle, kamu-özel işbirliği yaklaşımıyla dünyada bir çok altyapı projesi gerçekleştirilmiştir.

Türkiyede, kamu-özel işbirliği kapsamında yapılacak olan demiryolu projeleri Greenfield (sıfırdan yapılan) ve Brownfield (mevcut hattın yenillenmesi, genişlemesi vs) yaklaşımıyla yapılabilecektir. İlk uygulamada, özel sektör işletme dışında projenin projelendirilmesi ve inşaatı aşamalarında da aktif olacaktır. Böylece, ülkede ulaşım altyapı alanında bir çok havaalanı, otoyol, köprü, tünel vs. Yap-İşlet-Devret yöntemi ile gerçekleştirilmiştir. Demiryolu alanında Türkiyede bu tarihe kadar benzer bir Yap-İşet-Devret projesi gerçekleştirilmemiştir. İkinci yaklaşımda (Brownfield), özel sektör ve daha doğrusu özel işletmeci firmalar mevcut hattın iyileştirilmesi ve daha etkili bir biçimde hizmet sunmasında katkı sağlamalılar. Özel sektör sağladığı kaliteli hizmetten de gelir elde edecektir. TCDDİ'nin ülkede yüksek-hızlı demiryolları ağının geliştirme ve mevcut hatları daha verimli kullanma hedeflerini göz önünde bulundurduğumuzda, gelecek yıllarda yoğun bir şekilde bahsedilen yöntemler söz konusu olacaklar. Bu nedenle, konuyla ilgili geniş kapsamlı araştırma ve değerlendirmeler yapılmalı, dünyadaki benzer uygulamalar incelenmeli, artısı ve eksisi incelenmeli ve Türkiyede daha önce diğer alanlarda gerçekleştirilmiş benzer uygulamalar ayrıntılı bir şekilde irdelenmelidir. Literatürde, dünyanın her tarafından bu gibi uygulamaların lehinde ve alayhinde yapılmış olan araştırmalar mevcuttur. Bu tez kapsamında, ilk adımda dünya örneklerinden yapılan değerlendirmelerden yola çıkarak, ülkemiz adına kapsamlı ve tarafsız bir araştırma yapmayı amaçlıyoruz.

Bilindiği üzere, demiryolu sektöründeki faaliyetler çok-yönlü, çok-kapsamlı ve çok-karar mercililer. Kamu-özel işbirliği kapsamında yapılmış olacak demiryolu projeleri doğal olarak üç farklı kitleyi muhatap alacaktır. Bunun içinde kamu temsilcisi altyapı

ve yasal süreçleri sağlamakla, ve özel işletmeci firmalar anlaşma kapsamında tren hizmetleri sunmakla mükellefler. Üçüncü çıkar grubü ise çeşitli sosyo-ekonomik profillere sahip olan yolculuk eden misafirler ve hat kullanıcıları. Bu üç çıkar grübünün takip ettikleri amaçlar bazı noktalarda taban taban zıt sayılıyor. Örneğin, yolcular zaman tercihlerine uyan en uygun ve ucuz treni bulmaya çalışırken, işletmeci firmalar olabildiği en yüksek fiyatlara bilet satışı yapmak isterler. Kamu sektörü özel işletmecilerden yüksek oranda hatta erişim ücreti toplamaya çalışırken, işletmeciler bu rakamı mümkün olabilecek en düşük rakamlarda tutmaya çalışırlar. Kamu yetkilileri halka hizmet açısından, yapılan projenin daha geniş kitleleri uygun şartlarda kapsamk isterler ama doğal olarak özel işletmeciler bu konuda aynı duyarlılığı göstermeyebilirler. Bu konulara dikkat edildiğinde, kamu-özel işbirliği kapsamında bir demiryolu projesi yapılacak ise, sistemin çok derin ve ayrıntılı analizi yapılmalı ve olabilecek zıtlıkları daha ilk aşamalardan ve başlamadan resetleyip gereken önleyici tedbirleri almakta büyük fayda olduğu ortaya çıkıyor.

Böyle bir ortamda, optimizasyon yöntemlerinin kullanılması son derece verimli ve sağlıklı incelemeler ve analizler sunabilir. Her nasılsa, geleneksel optimizasyon yöntemleri bu alanda yetersiz ve gerçeklilik dışı kalabilir. Bunun nedeni, bu tarz yöntemlerin çok yönlü ve çok-amaçlı hedef fonksiyonlarının alınıp, yerine sistem genelinde tek bir amaç varmış gibi bir ortam yaratmasından geçer. Başka bir ifadeyle, geleneksel optimizasyon yöntemi kamu-özel işbirliği demiryolu projesinde bahsı geçen üç zıt düşebilen çıkar gruplarının tek ve sistem genelinde ortak bir amaçı takip etmeye indirgiyor. Bu yaklaşım, yapılan model ve analizi tamamen gerçekçilikten uzaklaştırır. Gerçek dünyada, böyle bir uygulama olacak ise her çıkar grubu öncelikli olarak kendi çıkar ve menfaatini ön planda alır ve kendi karını en üst düzeyde tutmak ister. Bu noktada, model kurma ve analiz etmek için daha sağlıklı ve gerçekçi bir yönteme ihtiyaç duyuluyor. Oyun kuramı (game theory) böyle bir değerlendirme ortamı sağlamak için olabilecek en uygun ve gerçekçi bir araçtır. Böylelikle, tez kapsamında iki farklı yaklaşımla oyun kuramı kullanılmıştır. İlk aşamada, karar vericilerin kısa ve uzun vadede olabilecek bütün menfaat çekişme sebepleri ve onlara alınması gereken tedbirleri dünyada gerçekleşmiş olan demiryolu projeler üzerinden ve basit 2×2 oyunlarla ele almıştır. İkinci adımda ise, cooperative game non-transferable utility kullanarak Anakar-İstanbul hızlı tren hattı üzerinde model kurulmuştur ve "bargaining problem" için "Nash solution" mantığına benzer bir yöntem geliştirilmiştir. Yolcu verisi toplanması için İstanbul Pendik durağında 191 kişilik bir anket yapılmıştır. Modeli geliştirmek için "GoLang" programlama dili kullanılmıştır.

Sonuç olarak, oyun kuramının sunduğu değerlendirmelerin kamu-özel işbirliği demiryolu prjelerinde daha ilk etaptan muhtemel sorunları öngörüp ve her türlü aksilği önlemek adına alınması tedbirlerin sunulmasında faydası görülmüştür. Ayrıca oluşturulmuş model özel işletmecilerin servis saatleri ile gereken ayarları yaparak her üç çıkar grubunun daha memnun olacaklarını ortaya koymuştur.

1. INTRODUCTION

Transport plays a pivotal role in social and economic development of countries around the world and it is a key driver in boosting more competitive economies. Transport facilities and infrastructures pave the way for realization of a worldwide goods supply and service delivery. Besides, they connect people to jobs, health centers, education and etc. Thus, improvement, development and modernization of transport infrastructures such as railways, highways, ports, airports and urban systems are the matters of paramount importance. An economy with inadequate and incomplete transport infrastructure is always doomed to under-development and experiencing a sustainable progress would be somehow impossible in such an environment.

In general, transport infrastructures require access to remarkable amounts of land which makes them very sensitive to political issues. In addition, such facilities require long term and huge sunk capital. Consequently, transport infrastructures necessitate significant support from governments. However, economic crises and some deficiencies in provision of public infrastructures by many governments around the globe have demonstrated that commercial discipline, expertise and capital of private sector can positively contribute to the delivery of transport facilities. Within this context, this study aims at evaluating the effects of the involvement of private sector in provision of transport infrastructures and tries to propose an approach to measure the efficiency of the participation of private operators in an open access rail market.

1.1 Motivation for the Study

It is a well-known fact that providing a seamless network of transport acts as a catalyst for a sustainable economic growth of a country. Around a century and a half ago, the backbone of such a network was supported by rail for connection of heavy rail connecting ports, industrial complexes, agricultural areas and mines. Animation

and stimulation of trade, connection of production sites to the international and regional markets, promotion of the integration of cross-border and national regions and facilitation of access to the international markets, labor market, public services and educational centers were all the issues to be actualized by development of railways in a global scale.

Compared to the other modes of transport such as air and road, rail transport is more energy efficient and investment in rail transport can lead to minimized CO_2 emissions and lowest possible carbon footprint while following transportation strategies. As for freight transportation, railway is the most efficient means of transferring bulk commodities from production centers to the airports and ports. Furthermore, High Speed Rail (HSR) systems can also be a serious substitution for long-distance air and road transport.

Despite the pioneering role of the railways in providing transportation networks, modal share of the railways fell critically and it lagged behind air, highways and water transport in the Post-Second World War era (Tomes, 2017). The demise of rail is mainly associated with national barrier effects and monopolies in studies of many researchers (Laurino et al, 2015; Pittman, 2007; Pittman et al, 2007; Jensen. 1998, Shaw et al, 1998). However, incessantly-growing traffic demand, congestion, climate change adversities, and energy supply are the matters to be continuously faced by contemporary governments. Thereby, governments are naturally obligated to cope with these problems and be in search of more sustainable solutions. The first remedy springing to the mind is revival of railways inasmuch as they are the most energy efficient means of transport and high occupancy vehicles and HSR services have proven this matter, particularly in Western Europe and the Far East.

From this point of view, Turkish government decided to enhance the rail sector by allocation of more budget from 2000s on. This approach was not only aiming at developing the railway network of the country, but also was in parallel with Turkish government's goals of integration to the European Union (EU) since a very determinant factor in EU membership of Turkey is a regional well-developed and integrated rail network of the country. On the other hand, Turkey's strategic location and being on the corridor of Eurasian and Middle-Eastern countries is an important parameter indicating the high potential of rail investments in the future.

In Turkey, despite some recent deregulative reforms, all layers of railway network including infrastructure provision and management, and operations are being controlled in a monopolistic frame. Indeed, in Turkey, some mega transport projects such as airports and highways have been constructed by participation of private investors but as yet there is not any realized rail project in a similar manner.

Turkey tends to develop some part of its HSR network by collaboration of private sector in close future. Besides, formation of an open access rail market in which authorized private operators may have fair access to the infrastructure is targeted for some of existing, under-construction and projected rail lines. In such an environment, it is necessary to have a comprehensive perception of public-private collaborations and its pros and cons. It is also advantageous to learn lessons from analogous national and international experiences. The major motivation for this study is to provide such a framework. In addition, we set our sights on presenting a simulator to model the liberalized rail market state in a realistic manner with regard to the inclinations and interests of all involved actors in the process.

1.2 Background and Objectives

In a classification proposed by Knieps (2004), the layers of a rail network are as follow:

- Infrastructure provision: construction of track and other fixed structures
- Management of infrastructure: track management and control of the rail traffic
- Operations: rail transport services

From the very beginning, Turkish State Railways (TCDD) (with different corporate names during Ottoman and republic periods) has had a legal monopoly over all above-mentioned layers for both passenger and freight transport. Numerous investigations have been made by many researchers to evaluate the inefficiency of monopolistic marketplaces in various sectors (Shahiki Tash et al, 2015; Wang and Chen, 2012; Neumann, 1999). Generally, monopolies lose their motivation to become more efficient and innovative in the course of time since they do not have any competitor in the market. Deadweight loss which is the potential gains that does not go to the service supplier or consumer is an inevitable component of a monopoly.

Therefore, the market fails to supply the socially optimal service where the monopolistic power restricts output to reach the purpose of profit maximization. In brief, in absence of competitors in the market, it is challenging for a monopoly to remain competitive and to self-regulate in the process of time. Figure 1.1 illustrates the market state under competitive and monopolistic conditions.

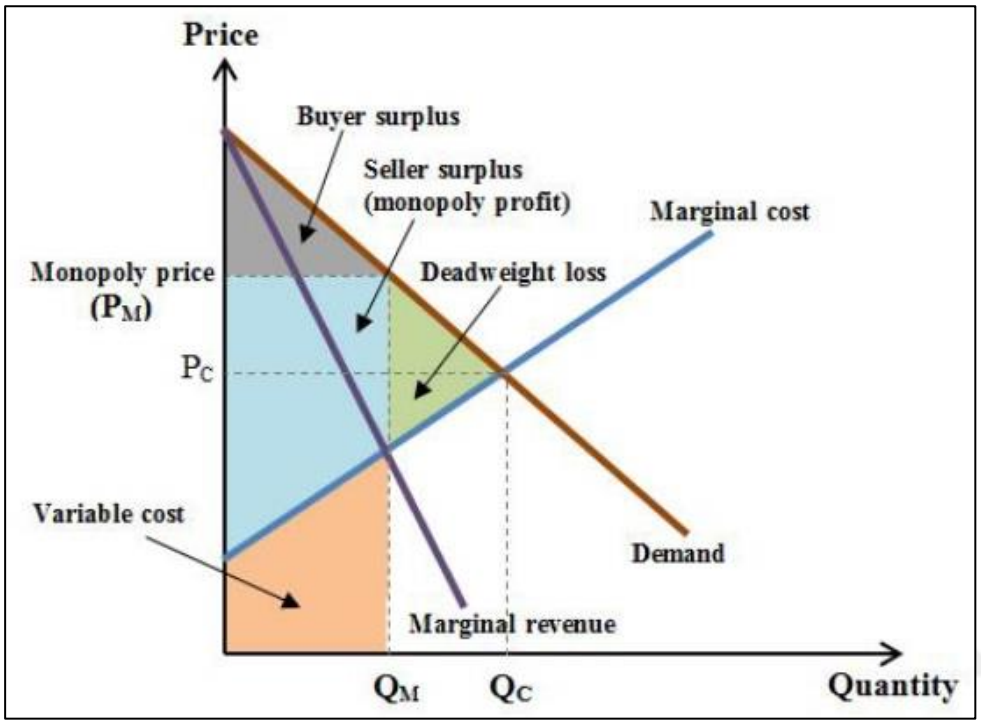

Figure 1.1 : Deadweight loss and inefficiency in a monopolistic market.

In the rail market, the number of passengers or the amount of goods to be carried is plotted on X axis and the costs and revenues per passenger or tonnage are shown on Y axis. As is clear from the figure, if the incumbent monopoly tends to increase the quantity (passengers or goods), it has to mark down the prices which leads to a lower total revenue for the existing level of services. It is also a known fact that in transportation, the demand-supply is inelastic (Preston et al, 1999) and this may give no incentive for the monopoly to make any difference in the system. With these explanations, in case of client-attracting-oriented price reduction strategies, the marginal revenue of the monopoly lies under the demand curve. In this situation and just like all neoclassical firms, the incumbent monopoly may select a quantity value (Q_M) in which marginal revenue, M_R and marginal cost, M_C coincide. In presence of perfect competition in the market, there would be such a point in which M_R still equals to M_C with lower price, P_C and higher quantity Q_C. This socially-efficient

combination of quantity and prices in a competitive market occurs when M_R absolutely lies on demand curve. In such a market state, there would be no deadweight loss (Pham, 2013).

Governments have been in quest of various methods and regulations to remove the mentioned inefficiencies in rail market and limit the monopolistic power (Laurino et al, 2015). On the other hand, global economic crisis of 2008 has remarkably constrained the fiscal space in many countries and allocation of public funds to new infrastructures such as railways has faced serious problems (Cuttaree and Mandri-Perrott, 2011). The mentioned factors have persuaded many governments to boost competition in the rail sector and erase monopolistic barriers. This new approach puts private sector at the forefront and gives it a great role in delivering new railway infrastructure, maintenance systems and rolling stock under Public-Private Partnership (PPP) framework. Some European countries pioneered this nascence by introduction of market liberalization by means of vertical separation of rail infrastructure provision from operations (Feuerstein et al, 2018; Tomes and Jandova, 2017; Finger, 2014; Laabsch and Sanner, 2012; Cantos et al, 2010; Drew, 2009). The major goals of such a liberalization are to create less public-subsidies-reliant sustainable financing methods, enhance productivity, introduce independent regulatory authorities and to promote the interoperability (Yvrande-Billon and Menard, 2005).

Subsequent to the realization of such liberalized railway markets, three interest groups including passengers as service users, public entities and private operators transpire whose thoughts and objectives are somehow antipodal. Passengers tend to have access to the rail services compatible with their timeline and budget. Private Train Service Operators (PTSO) try their utmost to maximize their profits. Thus, they have to analyze the costs including but not limited to the rolling stock leases, maintenance, energy costs for traction, staff, Track Access Charge (TAC), fixed and variable charges related to the network and some other expenditures such as advertisement, rental costs and etc. in a careful manner. Each of these costs has a complicated nature in essence. Vehicles' age and the equipment fitted to them seriously affect the lease costs. High speed operations require greater maintenance levels. Services with on-board facilities increases staff costs. Type of rolling stock and the annual mileages designate the TAC level to be paid to the Infrastructure

Provider (IP). Train sets' energy source is also an important factor to be considered where electric rolling stock is more efficient than diesel one. In addition to all these, the private operating firms must pursue effective pricing strategies for ticketing as one of their most important income sources. When it comes to the public party, they chase two principal goals. Primarily, they are in charge of providing inclusive train services which are appealing for citizens and users with various socio-economic profiles. Furthermore, they seek effective ways to compensate for a remarkable portion of track expenditures via applying TAC regimes to the private train operators.

As is clear from above-mentioned arguments, provision of public infrastructures such as railway network under PPP framework incorporates a number of interest groups with different anticipations and priorities. However, it is not straightforward to make trade-off among these groups since their actions and reactions are completely interrelated and every single actor in the system naturally follows its own goals in an individualistic manner.

An open access rail market is a multi-criteria multi-decision-maker task in which conflicts are generally inevitable in long run. There is a vast range of methods to evaluate and solve such problems and conflicts such as "strategic conflicts" (Li et al, 2004), drama theory (Howard, 1999), and Graph Model for conflict resolution (Fang et al, 1993). The major problem in utilization of conventional optimization methods in modeling these relations and conflicts is in connection with their simplifying and unrealistic assumptions. They usually convert the problem to a single decision-maker problem in which a single composite objective is being pursued by all parties and actors and supposes that the entire system acts as a whole. A typical feature of such an approach is the existence of a perfect cooperation among all involved decision-makers to reach the system-wide optimized resolution. However, when it comes to the real life, the environment might not be that much optimistic. In real circumstances, each decision-maker tends to outsmart the opposite side to reach her or his own objectives by anticipating the others' decisions and taking appropriate steps. This implies that in case of the presence of interest conflicts, it is logical to use methods that are individualistic and user-based rather than system optimization methods.

The point which is often neglected in conventional methods has to be handled by alternative approaches. At this point, "game theory" presents powerful tools to make up for the mentioned shortcomings by proposing the results closer to the practice as they reflect the realistic behaviors of the players. In contrast to the conventional optimization methods, game theory assumes that each player plays the game to optimize her or his own objectives. In game theory, the players are also aware that the decisions of all players affect the payoffs and decisions of the others. Thus, the players have to have a comprehensive and subtle perception of the system, the rivals, the strategic decisions and their reciprocal effects and the short, mid and long-term outcomes.

The major objectives of this study are to comprehend the PPP applications in the rail sector and present a simulation method which strategically evaluates the cases of public party, private operators and passengers in an open-access rail market in a very detailed manner. This multi-objective multi-decision-maker problem is implemented through the platform of GoLang programming language and is inspired by Non-Transferable Utility (NTU) cooperative game and Nash bargaining solution with some required and subtle improvements. The model will analyze PTSOs' benefits and losses, passengers satisfaction of the services and IP's state in various scenarios.

1.3 Outline of the Thesis

In Chapter 2, the research problem is described by a review of the literature. A comprehensive review of PPP, its applications in various sectors in the world and Turkey, the advantages and disadvantages of their application, and liberalization of railways and their regulative framework are included. The methodology for the study is given in Chapter 3 with a mathematical recall and analysis of the conducted Stated-Preference (SP) survey. It also includes the applicability of game theory in conflict resolution of PPP rail projects. Chapter 4 encompasses the case study which is inspired by the Istanbul-Ankara HSR and evaluation of the market analyses from the viewpoint of passengers, PTSOs and IP applied in four different scenarios. Finally, the conclusions of the study are presented in Chapter 5.

In brief, this thesis presents a multi-objective optimization model for a liberalized rail market and applies a game theoretic approach in the open-access market by

development of a computer program using GoLang language. Table 1.1 outlines the objectives of the study, the research tools and related outputs.

Table 1.1 : Outline of the research.

Objective	Research tools	Outputs required
A comprehensive understanding of PPP and the differences with traditional procurement	Review of published PPP guidebooks and researches	Understanding the roles of public and private partners
Addressing the conflicts and problems while applying PPP methods	Review of risks	Providing an appropriate risk allocation mechanism
Provision of a powerful tool to evaluate behaviors of partners in the PPP project	Review of conventional optimization methods and game theory	Evaluating PPP rail conflicts by 2x2 games
Market liberalization modeling	Review of fundamentals of Non-Transferable Utility (NTU) game theory	Provision of a case study model
Develop a research strategy to test the model	Programing using GoLang language	Evaluating the cases of passengers, private and public parties in an open access rail market

2. LITERATURE AND RESEARCH QUESTION

In this chapter, at first step a brief history of Turkish railways and TCDD's future outlook is given. Afterwards, a comprehensive overview of PPP is presented. Rail market liberalization and deregulative legislations in Europe and Turkey's perspective are given then. World-wide PPP experiences and lessons for TCDD are also presented. Some important inspiring researches are then evaluated in detail at final step.

2.1 Turkish Railways in the Course of History

Construction of the first rail line in the history of Turkish railways dates back to 1856 and Aydin-Izmir line. In general, it is possible to subdivide the history of Turkish railways into the following ages (Urban and national rail development in Turkey, 2015):

- Pre-republic period (Ottoman Empire)
- Republic period between 1923 and 1950
- 1950-2000
- After 2000s.

During the Ottoman Empire age, construction of railways was mostly granted to the French, German and British authorities and each of them expanded the rail network in their realm of influence. Indubitably, these countries were following their own politics and the lines shaped up by the foreign governments were in coordination with their economic and political goals rather than national interests of Turkey.

After the proclamation of the republic in 1923 and in the second period, the state took the control of the railways and commenced expanding the network in parallel with the national interests of the country and in support of Turkish financial interests.

During the third period which is coincided with Post-Second-World-War era, the expansion of railways dramatically fell behind the highways. However, this trend

was also true for almost all countries across the world in those decades. Modal share depreciation of railways in this period is given in Table 2.1.

Table 2.1 : Share of railway in national transportation of Turkey (Urban and national rail development in Turkey, 2015).

Years/share %	Passenger	Freight
1950	42.2	68.2
1960	24.3	52.9
1970	7.6	24.3
1980	4.6	11.8
1990	2.5	9.8
2000	2.2	5.4
2010	1.6	5.3
2011	1.6	5.1
2012	1.1	4.8
2013	1.0	4.4
2014	1.1	4.6
2015	1.1	3.9
2016	1.0	4.3
2017	1.0	4.3

Later decades of 20th century was witness to the revival of railways in Western European and Far Eastern countries by emergence of new technologies in the rail sector and realization of economic, energy-efficient and environment-friendly HSR. Turkey decided to catch the mentioned trend since the very first years of 2000s and allocated more budget to the construction of HSR lines and renovation of existing network. Following this trend, the forthcoming years may be considered as a golden age for rail revival in Turkey and the government has to find effective financing methods and prospective legislations to accelerate the process.

2.2 Infrastructure Development and Regulations in Turkish Rail Sector

Rail sector in Turkey was in need of a fundamental reform. The Ministry of Transport was not exercising a regulatory or supervisory role. Turkish State Railways (TCDD), a monopoly responsible for train operations, infrastructure and maintenance, was inefficient and reliant on state funding. There were no separate accounting procedures for its various operations. Although the ministry and TCDD completed an EU-funded programme on restructuring and strengthening the Turkish railway sector in January 2007, no progress was made on implementing EU regulations or national legislation proposed by the project. Therefore, a more detailed

implementation strategy and plan was needed. The objective of this reform was to establish the framework for the restructuring of the railway sector and, thus, prepare it for a transparent and competitive market for the benefit of its customers.

The first step involved analyzing existing organizational structures within TCDD and the Ministry of Transport in the context of the legislative package proposed by a previous EU-funded programme. Then, a strategy was drawn up to create the framework necessary for reform, taking into consideration the best railway-reform practices from EU member states. This included an action plan to establish the necessary regulatory, safety and accident investigation authorities and reorganize TCDD's administration. Measures were also undertaken to improve infrastructure allocation and charging within TCDD, in line with EU rules and practices in EU member states.

National rail safety rules were also drawn up, after a detailed analysis of existing Turkish legislation and EU requirements. Legislation on the interoperability – or technical compatibility of infrastructure, rolling stock, signaling and other subsystems – of TCDD with the European rail network was also improved. On the basis of these studies, two laws were enacted that changed the principles on which Turkish railways operate.

The Law regarding the "Liberalization of Railway Transportation in Turkey No. 6461" (the "Law No. 6461") replacing the state monopoly in the rail network and train operation with a competitive and transparent market environment has entered into force as of 1 May 2013. The long-awaited liberalization initiative paves the way for the legal harmonization of railway transport in Turkey with the European legislation which is relentlessly striving for greater competitiveness in the rail network and train operation services reiterated via the Fourth Rail Package proposed by the European Commission in January 2013.

Although the Law No. 6461 is supposed to be the cornerstone of the liberalized railway transport policies of the Turkish government, it is not the first step taken to achieve such goal in the railway sector. Enactment of the Law No. 6461 has already been recalled by adoption of the Governmental Decree concerning the Organization and Duties of the Ministry of Transport, Maritime Affairs and Communication No. 655.

The Decree No. 655 established a special service department named as General Directorate of Railway Transport Regulation (the "Railway Regulation Directorate"), that is attached to the Ministry of Transport, Maritime Affairs and Communication (the "Ministry"), vested with special regulatory powers such as:

- Specifying operation and service principles as well as financial and professional requirements applicable to service providers and issuing licenses for operators wishing to take part in the railway transport business;
- Keeping a registry of all and any kind of rail vehicles;
- Specifying minimum safety requirements for all operators and granting the relevant safety certificates to those complying with these requirements;
- Specifying the rules and principles in connection with the public service obligations;
- Settling disputes that may arise between the market players relating to the right of access to the railway infrastructure, allocation conditions and charges required;
- Conducting technical and safety inspections; and
- Fixing minimum and maximum fees for provision of transport services including use of infrastructure.

In addition to the foregoing authorities listed in Article 8 of the Decree No. 655, the Railway Regulation Directorate is authorized to issue -when required- other secondary legislation pursuant to Article 28 of the Decree Law No. 655 in order to further elaborate on issues like price, duration, scope and form of the licenses. Likewise, the Railway Regulation Directorate is also entitled to impose administrative sanctions including the administrative fines.

Nonetheless, Temporary Article 8 of the Decree Law No. 655 announced that the powers attributed to the Railway Regulation Authority relating to liberalization of the rail sector shall not gain legal effect unless the State monopoly in the railway sector is removed. In this respect, eagerly-awaited enactment of the Law No. 6461 will mark the turning-point as it enshrines the mentioned removal.

The scope of the Law No. 6461 is limited to railways at the national level. Therefore, undergrounds, trams and light rail systems along with rail networks within mining and industrial facilities do not fall within the scope of the Law No. 6461. Apparently, the Law No. 6461 has entered into force upon its publication in the Official Gazette. The proper implementation of the railway market restructuring cannot, however, be entirely ensured unless the relevant secondary legislation is issued. According to Article 6 of the Law No. 6461, it is envisaged that a regulation setting the conditions for qualifying as a public or private operator entitled to perform services in the relevant markets (i.e., network operator or train operator) will be issued.

For the purpose of liberalization and restructuring of the Turkish rail market, the Law No. 6461 identifies three types of market activities to be performed by public or private companies:

- Construction of the railways which will be under their disposal,
- Operation of the railway network which will be under their and/or third parties' disposal,
- Operation of the trains by using the national railway network (i.e., carriage of goods/passengers)

Public corporations and any kind of commercial enterprises are entitled to carry out those activities if and to the extent that they comply with the technical and safety requirements, and are granted the license by the Ministry. The network operators are obliged to determine the fees, which are required to be paid by the train operators in an equal and non-discretionary manner considering the right to access to the network.

By virtue of the Law No. 6461, TCDD which used to perform all infrastructure construction, maintenance and operation as well as train operation related activities in a monopolistic way will enter into an unbundling process of its railway operation activities and train operation activities.

More precisely, the Law No. 6461 discharges TCDD from its train operation related duties. It provides that a new affiliate company of TCDD to be incorporated as a joint stock company under the trade name of TCDD Taşımacılık A.Ş. will assume such duties and powers from now on. Upon completion of its registration, TCDD Taşımacılık A.Ş. gained its legal entity and would be subject to the provisions of the

Decree Regarding State Economic Enterprises No. 233 since it was entirely owned by the TCDD.

As a requirement of the unbundling process, TCDD Taşımacılık A.Ş. will possess its own financial, legal and human resources allocated to the smooth functioning of the train operation business. According to Temporary Article 1 of the Law No. 6461, certain assets of TCDD will be transferred to TCDD Taşımacılık A.Ş. through a spin-off process which concerns all the relevant vehicles and trains along with the personnel employed in the train operation service unit. Among properties necessary for providing train operation services, movables will be transferred to TCDD Taşımacılık A.Ş. whereas the immovable will be allocated for utilization by TCDD Taşımacılık A.Ş. for ten-year period. Besides, lawsuits and execution proceedings relating to disputes arising from train operation related activities of TCDD will be followed up by TCDD Taşımacılık A.Ş.

All relevant transfers are required to be completed within one-year time subsequent to the incorporation date of TCDD Taşımacılık A.Ş. Meanwhile, TCDD will continue to offer train operation services. According to the new structure established by the Law No. 6461, the authority and duty to regulate the railway traffic along the lines owned by TCDD and the lines to be constructed by other railway operators will remain within the competence of TCDD. In other words, TCDD will be the only authority in charge of directing the railway traffic flow in exchange of the fees levied on the operating companies. Further, operating trains will fall within the sphere of TCDD Taşımacılık A.Ş. or other train operating companies once certified by the Ministry.

Finally, TCDD and TCDD Taşımacılık A.Ş. will still be subject to the Public Procurement Law No. 4734; however, procurement of goods and services by TCDD and TCDD Taşımacılık A.Ş. from other affiliates of TCDD are exempt from the Public Procurement Law No. 4734 which has been enacted as a part of the approximation efforts of Turkish legislation to European Union Law.

The Law No. 6461 seeks to rapidly improve and expand the railway network by giving the lead to both private and public investors in infrastructure projects. In the forthcoming structure, TCDD will acquire title to all immovable properties that have been allocated to its services and will be able to undertake construction of new

railway lines in its own capacity. However, since infrastructure investments demand excessively high funding, the Law No. 6461 acknowledges that there will be allocations deriving from the Ministry budget. Such state-funding may finance programed projects including construction of the high-speed train lines as well as conversion of the existing lines into double-track or multiple-track lines, their repair and maintenance works along with construction of other complementary facilities for signalization, electrification and communication services.

The Law No. 6461 facilitates private sector involvement in infrastructure investment by allowing expropriation of the necessary property for realization of the project by the Ministry on the condition that the private investor accepts to pay for the expropriation costs. In such case, the private company will be entitled to an easement right over the expropriated lands for a period up-to forty-nine years and will be authorized to operate the relevant lines during this period. When operation period elapses, the Ministry regains full property of the relevant lands and facilities constructed on them.

It must be noted that the private or public investors can either prefer to operate the railway network personally or prefer to delegate such operation rights to a third party operator. This possibility applies to both existing lines and to those that will be further constructed by private or public companies.

Passenger transportation by train to ensure the freedom of movement remains as one of the exceptions to competitive market policies. In this respect, it is essential to make sure that everyone has access to a railway transportation service at affordable prices. The Law No. 6461 allows the Ministry to delegate such liabilities within the framework of bilateral agreements to be entered into with public or private train operators. Article 8 of the Law No. 6461 sets the compulsory content of such agreements. Accordingly, the following provisions will, among others, take place in the agreements:

- term of the agreement;
- line along which the transportation will be realized;
- transport fee for line passengers;
- minimum frequency of circulation; and

- methods applicable for fee payment

As expected, the Law No. 6461 recognizes that performance of such public service liabilities may prove to be economically unsustainable and thus necessitate allocation of compensation from the central Ministry budget. With the aim of minimizing the uncompetitive impacts of public service compensations and prevention of cross-subsidizing, it is required that the train operator companies or public entities shall keep income and expenditure accounts and accounting records separately in relation to each of the following activity areas; carriage of goods, carriage of passengers and performance of public service obligations.

The Council of Ministers is normally entitled to determine the lines within the scope of public service obligations and relevant train operators which will perform public service obligations. Nevertheless, pursuant to Article 4 of the Law No. 6461, TCDD Taşımacılık A.Ş. will be responsible for public service obligations for the first five-year term upon entry into force of the Law No. 6461.

The Law No. 6461 defines a transition period of 5 (five) years starting from the effectiveness date of the Law No. 6461 during which activities of TCDD and TCDD Taşımacılık A.Ş. including public service obligations will be financially supported with allocations from the central budget. The state-funding aims to help TCDD maintain its budget balance while the market growth and transaction volume are insufficient to afford its expenditures with its main income source namely, infrastructure utilization fees. While TCDD receives direct financial support, budget deficit arising from activities of TCDD Taşımacılık A.Ş. will be eliminated via allocations received from TCDD to be added to paid capital of TCDD Taşımacılık A.Ş.

Finally, it can be noted that involvement of private sector in the railway network operation and transportation services will pioneer the liberalization of Turkish railway sector that ultimately needs large scale investments. Tough the licensing regime applicable to the private companies will be governed by the regulation to be issued by the Ministry; the Law No. 6461 clearly lays down the principle in this regard. Given the then monopolistic structure of TCDD, unbundling of the network operation and train operation activities of TCDD and establishment of TCDD Taşımacılık A.Ş. as the state-owned transportation company are of material

importance. However, it should also be borne in mind that the regulation of public service obligations and long term control of state aids to TCDD and TCDD Taşımacılık A.Ş. are also vital for the achievement of liberalization and smooth-operating market.

2.3 Public-Private Partnership Overview

In previous chapter it was mentioned that the governments are looking for measurements to limit the monopolistic powers and also trying to find alternative solutions to finance the public infrastructures. Taking advantage of the private sector's financial and technical power is the most important tool in realization of this goal. Within this direction, private sector is incorporated into the process and a new approach for design, construction and operation of infrastructures is introduced under Public-Private Partnership (PPP) framework. Although application of PPPs has gained popularity in only recent two decades, its early applications date back to even 18th century (Hodge and Greve, 2007). However, extensive utilization of PPPs in various sectors began throughout the 1990s (Abdel Aziz, 2007; Schaeffer and Loveridge, 2002; Zhang and Kumaraswamy, 2001).

PPP, P3 or 3P is defined as a long-term contract between a public authority and private parties to provide a public infrastructure, service or asset in which a remarkable portion of risks and management responsibilities are being borne by private party and remuneration of private party is performance-based (Url-1). Some researchers believe that on-budget and on-time delivery of projects by private party is more expected compared to the conventional approaches (Eggers et al, 2010; Thompson and Budin, 1997). In contrast, some scholars believe that PPP is only a rhetoric governmental use of outsourcing and a language game in which governments tend to conceal the negative connotation of outsourcing among citizens (Hodge and Grave, 2010; Teisman and Klijn, 2002). Hall (2015) believes that private corporations naturally tend to maximize their profits to survive. In essence, this is not compatible with ensuring universal access to quality public services and the environment. Some other definitions of PPPs are as follows:

- Due to the Canadian Council for Public-Private Partnerships (CCPPP), PPPs are cooperative ventures based on the expertise of each party between public

and private parties to deliver public needs in the framework of a proper resource, risk and reward allocation (CCPPP, 2013).

- OECD (2008) defines PPPs as agreements between the public authority and one or more private entities such as operators and financiers where private partners are responsible for the service delivery. In such cooperation, private partners' profit objectives and public party's service delivery goals must be aligned and a remarkable risk should be transferred to the private parties.
- PPPs are long-term contracts between public and private sectors where private sector delivers the public infrastructure on behalf of the public entity and the major responsibilities are taken by the private sector during contract time. Private parties are then being paid by public sector on a whole-life-performance basis (Infrastructure Australia, 2008).

PPP is different from traditional procurement since the private party takes more risk and bears more responsibilities during all stages such as design, financing, construction, maintenance and operation. It is also different from privatization in that the private party only owns the public asset for a predefined period of time and in the fullness of time the private party has to transfer it to the public party (Majanen, 2011). Another study suggests that the major difference between PPPs and other methods of procurement is the changing roles of public and private sectors. In this context, the public sector acts as the procurer of the services on behalf of the public rather than a direct service provider. Besides, the private sector is no more only a facility constructor and it acts as the service provider (De Lemos et al, 2003). The changes in roles of both parties are in respect to the following items:

- Risk transfer
- Value for money (VFM)
- Management
- Innovation

In almost all projects realized under conventional procurement methods, the risk is entirely retained by the public sector. In contrast, a PPP project transfers the risks to the party which is best suited to carry them. However, to avoid future problems, it is vital to identify the possible risks and each party should be fully aware of the

undertaken risks. Generally, in PPP projects it is proper to transfer the risks of construction and maintenance to the private partners. On the other hand, it is not appropriate to fully transfer the mentioned risks to the private sector where the return on the project is subject to public party. Finally, the critical services to the society must on no account end up with failure and public sector has to accept the ultimate responsibility of operation of such services without regard to the risk allocation terms. An obvious example of such a failure was the UK National Air Traffic Services PPP (Shaoul, 2003).

Another important issue in selection of procurement method is to evaluate the value for money. Indeed, it is better for the government to electorate to ensure that the provision of the service delivers value for money. When a PPP procurement method is selected in provision of a service or an infrastructure, a detailed analysis of value for money should prove that the taxpayer would receive a better value during the lifetime of the service under selected method. In countries with developed PPP legislations, such an analysis and related framework are indispensable parts of PPP procurement. For instance, in England, a Public-Sector Comparator (PSC) provides such an analysis. In this manner, a report establishing the costs during operation of the service should be provided for both traditional procurement methods and PPP and only if the PPP is more profitable over time in provision of the project, it is explainable to apply the PPP method. Utilization of such analyses results in general judgments of the public sector based on lifetime commercial criteria. Lack of such analyses by experts in provision of a PPP service may lead up to unsuccessful projects in mid and long term which is a common problem in developing countries. Governments of many developing countries boast that they do not pay even a single penny while providing a service with a PPP approach. However, in future time spans they may pay astronomical prices as guarantees for the private partners.

Management role is another important factor to be considered while providing a public service under PPP methods. Based on the PPP type used, public sector's management role is remarkably different from that of traditional provision of public services. While a design and build type of PPP is performed, public sector has less impact on design and it has hands-off style of management in the construction monitoring. Where private party is incorporated into the operation and maintenance of a public service under a PPP contract, private party undertakes the management of

the mentioned activities and the role of the public party is to monitor the performance of the services. Hence, the payment for the provision of the services would be highly dependent on the service performance measured by satisfaction levels. This matter is a serious change of the role of public sector compared to the traditional methods and it triggers a significant change in the mindset of the public sector. In traditional approaches, operations were on the basis of direct service provision based on an annual budget. Within these approaches, there would be no service if the annual fund was not there and the available fund would be spent before the end of the year. However, financial analyses are not that easy under PPPs and they require a multi-annual perspective. This necessitates further skills of management and performance monitoring. This becomes more of an issue as most of the managers of construction companies wishing to involve in the provision of public services are engineers whom are excelled in short-term considerations rather than long-term environment of the construction process. Thus, in an environment where the private sector's income is spread over a long period of time, decision-makers of the private sector have also to change their mindsets and adopt themselves to longer planning cycles (Gunnigan, 2007).

Last but not least, innovation is another important factor considering PPP applications. It is widely-believed that involvement of the private sector in public service provision prompts the use of innovation and technology to maximize revenue intakes over the project's whole-life period (Chi et al, 2003). Introduction of such innovations by private party aims at reducing construction time and costs of operation and maintenance, savings with regard to construction overheads, and maximizing side bonuses and creating further opportunities in future.

While providing a public service under a PPP framework, it is necessary to analyze the social, legal, economic, environmental, political and technological aspects of the process in detail. Providing efficient and high quality services with a proper maintenance must be ensured throughout the lifespan of the project. Similar to the other types of procurements, legal framework of the PPP contracts must be regarded in a careful manner to define the duties, responsibilities, obligations and roles of partners. In some cases, PPP contracts can be in existence for long periods of time such as 30-40 years and a comprehensive legal frame is required. Lack of sector-oriented legislations for PPP applications may also lead to inconveniences and

problems. From an economic point of view, PPPs change the initial short-term capital expenditure to the long-term current expenditure. For instance, a public party may face serious difficulties while trying to provide millions of dollars to construct a hospital or to cover the growing maintenance costs. However, this problem may be resolved by involvement of the private sector such that private financier may bear the investing capital costs and on-going maintenance in return for an agreed rate of annual payment from the public side. In this context, a subtle analysis of risk allocation, demand forecast and etc. must be done. Otherwise, such ventures may be only a short-term panacea and the entire success of the project may be overshadowed. Thus, developed countries deem critical factors such as effectiveness, accountability, consumer rights, impacts on stakeholders, etc. in a holistic view (Webb and Pulle, 2002). Besides, environmental issues are now matters of paramount importance in infrastructural development of most developed countries and even the developing ones. Political issues are also very important while using PPP. The period for PPP contracts may reach 30-40 years while many governments around the world may only be in office for a period of at most 5-years. With this in mind, a government may tend to get credit with 20-30 years payback period now for services that the public will be paying for over the subsequent decades.

Undoubtedly, governmental authorities have to master the subject and have adequate information on practical issues to reach a successful implementation of a PPP project. However, lack of such awareness among the officials acts as a barrier in application of PPPs. This issue is particularly more obvious in the countries whose economy is unstable. The problem is addressed by many international institutions some of which are presented in Table 2.2 and they have provided related guidebooks and handbooks. The information given in these guidebooks are somehow shallow and lack the in-depth sector-specified knowledge. They explain overall processes of PPP applications, their characteristics and models and highlight the potentials of PPPs. However, these guidebooks do not include the required information on PPP practices in various sectors and in different circumstances.

Table 2.2 : PPP guides presented by the international institutions.

Institution	PPP guide
CDIA (2010)	PPP guide for municipalities
UNESCAP (2009)	A guidebook on PPP in infrastructure
UNECE (2008)	A guide to promoting good governance in public-private partnerships
ADB (2008)	PPP handbook
ASEAN (2006)	Guidelines for effective PPPs: meeting the region's infrastructure needs
EC (2003)	Guidelines for successful PPPs

2.3.1 PPP contract types

In this section, we try to describe in more detail the types of PPP contracts. In most cases, PPP projects present a validity period of 20-30 years. However, in some cases this contractual term might present shorter or longer periods. In fact, to persuade the private party to be involved in provision of a public service the length of the contract should be long enough and required incentives must be presented to them. Project type and policy considerations may actually define the precise term of contract. A well-planned PPP project satisfies decision-makers about demand for the services over the contract life.

To classify the PPPs, most references describe them with regard to three parameters including the type of asset or service, responsibilities of private party and income generation of private party. One major classification of PPP projects based on asset type is as follows:

- Greenfield projects
- Brownfield projects

In Greenfield, the PPP project involves a new asset and the private party is responsible of financing, constructing and managing new public assets such as hospitals, transport infrastructures, schools and etc. as described in their contract. In contrast, in Brownfield approaches the major role of the private party is to manage and upgrade existing assets in order to improve the underperformance of existing assets. Thus, in all PPPs the major focus of the system is on the outputs rather than inputs. In other words, compared to the traditional procurements PPPs concentrates on what is required rather than how it is to be done.

The other feature involved in classifying the PPPs is the private party's responsibilities. Private party's typical functions encompass design, construction or rehabilitation, financing, maintenance and operation. Design of the project deals with early development of the project concept to the output requirements. In provision of a new public asset, private party may be involved in construction phase of the project while for existing services, rehabilitating and improving the asset is undertaken by the private party. Besides, private party has to fully or partially finance the capital expenditures required by the PPP project. Generally, private parties are responsible for maintaining the assets during the contract life to a specified standard. The last feature is operation of the service where the private party may technically run the asset and provide bulk services to the governments or present direct services to the users.

Payment mechanism is the PPP's third defining characteristic where the private party can earn income from direct collection of fees from service users, being paid by the government based on the performance or a combination of both methods.

Some of the most important PPP models are described below (Majanen, 2011):

- Build-Operate-Transfer (BOT): this is a long-term contract between the private party and governmental authorities in which the private party develops a discrete asset and is responsible for design, construction, operation and maintenance of the service. In general, this type of PPP provides the private party the higher freedom degrees. At the end of the contract term the asset is transferred to the public party. In some cases, this type of PPP may be referred as Design-Build-Operate-Maintain (DBOM).
- Build-Own-Operate (BOO): the major feature of this type is that the asset is not handed back to the government and the private party retains the project ownership. Under this type of contract all rights and responsibilities such as financing, design, operation and maintenance are granted to the private party and such transactions may be exempt from taxes. Power plants and water treatment are the main industries in which this type of PPP may be used.
- Build-Own-Operate-Transfer (BOOT): in this type, the private party constructs the asset and owns it for the contract duration. The major goal of the private party in this method is to recoup the construction costs in the

phase of operation. The asset is transferred to the public side at the end of the agreement. This method is often used when the government faces a remarkable financial gap for provision of infrastructures such as hospitals and schools.

- Build-Transfer (BT): in this type, the private party is responsible for design and construction of the asset and the operation is undertaken by the public sector. This type of contract may save time and money for public side since they only have to work with a single entity rather than a complicated consortium mechanism. This model may also be referred as Design-Build (DB).
- Design-Build-Finance (DBF): in this method, the private party builds an asset and is responsible for capital costs only during the period of construction. This type has also some sub-branches such as Design-Build-Finance-Operate (DBFO), Design-Build-Finance-Maintain (DBFM) and Design-Build-Finance-Maintain-Operate (DBFMO). Regular payments may make these methods attractive for private parties where the mitigation of long-term risks is public sector's main motivation for such an approach.
- Design-Construct-Maintain-Finance (DCMF): this is very similar to DBFM and in this method; the private party provides the facility based on the specifications and requirements presented by the government and leases it back to the public sector. Prison projects are the most common area in which DCMF type of PPP is applied.
- Operation & Maintenance (O&M): private party operates services and maintains the infrastructure for the public sector with predefined obligations and to an agreed level under O&M contract. Generally, there are two types of payment to the private party in this method. In first one, the payment is based on a fixed amount and in latter case the payment follows a performance-based fee. In second case the concept of pain share / gain share is dominant where the private party earns more for over performance and has to undergo penalties for shortcomings.

- Lease: in this method, the private party is granted a leasehold interest of an asset by the public sector and the private side is responsible for operation and maintenance of the services with regard to the terms of the leasing contract.
- Concession: in this type, the concessionaire (private party) has exclusive rights of operation and maintenance of the facility in the framework of public party's performance requirements. Public entity owns the original asset and the private sector retains ownership of any improvements over the period of concession.
- Divestiture: this is the fully or partially transfer of an asset by the government to the private party. Thus, the private party would be the new owner of the asset.

Degree of private sector's participation and risk allocation in various PPP contracts is shown in Figure 2.1.

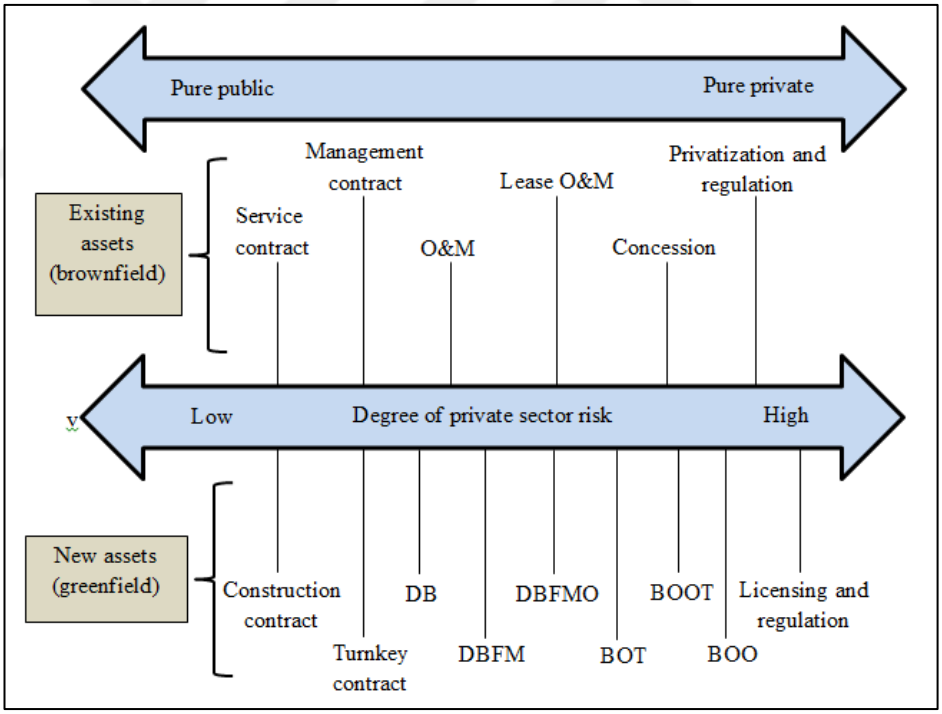

Figure 2.1 : Different PPP contract types with their scale of responsibility (Roehrich et al, 2014).

2.3.2 Typical characteristics of PPP

Table 2.3 summarizes the motivations of the governments while pursuing PPPs. These items clarify the governments' perspectives on determination of the PPP

programmes and selection of winning bidders. Thus, at the first step it is crucial to comprehend the common objectives of the governments while applying PPPs.

As is discussed in Table 2.3, each item has a remarkable impact on how both parties identify, prepare and implement PPP projects. However, the objectives and structure of the project would determine the process of bid selection where the criteria for provision of a service at the lowest price may differ seriously with those for innovative and technologic approaches. In brief, each project and each country may own their unique reasons while applying PPP which may evolve in the process of time as programme matures.

Table 2.3 : Common objectives for using PPPs (EPS Peaks, 2017).

objective	Considerations
Completing the project on-time and on-budget	To reach these goals, the private partner must have sufficient incentives to do so. For example, in long-term PPPs where the private sector is responsible for design, construction, maintenance and operation of the service, the private partner would be motivated to complete the project in earliest possible period since it would be possible for them to earn greater revenues in case the operations start sooner.
Increasing the efficiency of the market by appropriate risk allocation	A key factor in delivering a successful asset under PPP framework is the proper allocation of the risks. The risks must be tackled by the parties who are best suited to tackle them. If the risk allocation is not well-organized, the party whom is not best-positioned to carry the risk has to mitigate it at a cost higher than that for the optimal party.
Ensuring greater service coverage for the users	While applying PPPs, the governments are intended to provide greater coverage of the service for the system users. Thus, the public party selects the offer which is presenting the best investment commitment. This may lead to the provision of the greatest possible coverage.
Lowering the tariffs	While choosing the bidder, the public partner focuses on selection of a private partner who is able to provide the best value-for-money.
Attracting foreign investment in the country	Public sector has to present persuasive incentives to attract foreign investors. It is always desirable to balance the local and international investment in the country.
Promoting the monetization	This case is mostly effectual in brownfield PPP projects where the public sector can receive a large upfront lump sum while transferring the right of operating the existing facility to the private partners. In this case, the public party may reinvest this payment in other infrastructures.

Table 2.3 (continued) : Common objectives for using PPPs (EPS Peaks, 2017).

objective	Considerations
Providing better quality of service	To achieve this goal, the technical aspects of a private partner's proposal must overweigh its financial proposals. Incentives for motivating the private partner to provide a service of high quality must outweigh the penalties for lack of them.
Reducing maintenance costs	Naturally, the private partner would take extra measures and considerations while constructing an asset to prevent further repair costs during the contract term.
Improving technology and innovation	Governments must concentrate on utilization of innovative resolutions and technology while evaluating the bids. In this case, bidders may be willing to transfer the technology and knowledge to the public side. For example, in a toll road, the private party may be encouraged to use an automated system of toll collection where for the similar case, the public sector would be encouraged to use manual systems.
Optimizing the utilization of the resources	A key driver of PPPs is promotion of utilization and optimization of resources for both parties. Within this context, horizontal and vertical integration, economies of scale and critical mass are important factors in consideration of cost-savings and value generation.
Enhancing the competition	Public party has to make a fully transparent procurement so that the most qualified investors are attracted to the involvement in the project. If properly done, the best value-for-money may be guaranteed.
Separating regulations, construction and operations	When a private party is responsible for financing and operating a public asset for a pre-defined period of time, the conflict of interest between regulation/policymaking and operations/investment is separated.

Both public and private parties must provide significant input in PPP arrangements. Each party has its own roles throughout the PPP process. These responsibilities are outlined as follows:

Role of public sector:

- Identification of project objectives
- Accountability to citizens
- Prioritization and assessment of the project
- Conducting feasibility studies, analyzing value for money and project preparation

- Pursuing a market-oriented approach
- Project tendering and selecting the best bid
- Monitoring the project in all phases

Role of private sector:

- Ensuring technical and financial capacity
- Fair competition in bidding process
- Presenting an optimal value for money to the government
- Ensuring service quality and remaining in line with the commitments
- Sharing knowledge and expertise with public partner

PPPs have some features that differentiate them from traditional procurement. These differentiations are as follows (Shakibaei and Alpkokin, 2017):

- One of the key issues differentiating PPPs from traditional procurement is the funding sources. While providing a public service using traditional approaches, the country's national budget is charged for financing the project. Therefore, the government would select the proper contractor and the payments to the contractor may be realized in a number of phases based on the progress of the project. In contrast to the traditional procurement methods, PPPs follow a different method of financing and mostly hold the private party to finance the project. However, there would be proper mechanism for the private partner to remunerate its investment and make profit over the lifetime of the project.
- The other factor differentiating PPPs and other traditional methods of procurement is the concept and duration of the cooperation between public and private parties. In traditional delivery of a service, the relation between the private contractor and the public sector ends up when the construction phase of the project is over. However, in PPPs this relation lasts far longer and continues during operation and management of the asset. In some cases, this may take even 20-30 years.

- The third differentiating characteristic is the definition of requirements in both approaches. Traditional procurements are mostly input-based which means that for example the only important matter in construction of a new airport is provision of the terminals, the apron or other fixed elements. In contrast, PPPs are output based or objective-based approaches. Within this context, for the same airport project it is more important to discuss what is supposed to be achieved such as transportation of 100M passengers per year. Thus, PPPs are goal-oriented approaches and this would increase the efficiency of the infrastructure if well-planned.
- Last but not least, the matter of risk allocation is totally different in PPPs compared to the traditional approaches. There are a number of items menacing the success of an infrastructure project such as time and cost overruns, erroneous demand forecasts, commercial risks and etc. most of which are borne only by the public sector in traditional project delivery systems. However, PPPs tend to share the risks and make the party who is best-suited to undertake the specific risk as a responsible authority. This may remarkably transfer the risks from public party to the private partners in various phases and stages of the project.

However, it must be considered that the PPP is not a panacea for delivering all public services and infrastructures and a comprehensive evaluation of the project, objectives, advantages and disadvantages of each approach must be regarded in detail. Indeed, both of the public and private parties can benefit from PPPs if they work under clear rules and legislations and if the risks are allocated in a specialistic manner. In advance of the finalization of a PPP contract, several fundamental questions must be enquired as follows:

- Are there any similar and existing (un)successful PPP experiences in the country?
- Is the private sector of the country mature enough to participate in the provision of public infrastructure?
- Are there incentives for attraction of foreign investment in the country?
- Are there sufficient background and data for the project planning and evaluation?

- Is the capital required for completion of the project large enough to attract private party or foreign investors?
- Who is the project's majority owner?

2.4 A Brief History of PPP from All Around the World

Despite the fact that PPP is relatively a new term, the concept is well-established in the history and its applications date back to the centuries ago in a vast range of investments. Very first partnerships between the private investors and public sector were related to construction and management of post office networks for five-year periods in Roman Empire Era in more than two thousand years ago (EPS Peaks, 2017). In some cases, these agreements were also including the maintenance of associated roads along the networks. European countries implemented road pavements, canal constructions, waste collection and other types of public services through partnerships with the private sector in 16^{th} and 17^{th} centuries. Industrial revolution of 19^{th} century paved the way for realization of a rapid urbanization which required expansion of public services such as transportation, sewage systems, energy and etc. Actualization of such a goal was facilitated by incorporation of private sector into the process throughout concession contracts.

From the beginning of 20^{th} century and mostly due to the world wars the development and growth were halted in a global scale and basic infrastructures faced a declining trend and this was yet continued due to the oil crisis in 1970s and related economic slump. However, from late 1980s on, a shift back to participation of private sector was observed in provision of public services and infrastructure assets. Finally, the financial crisis of 2008 reversed this trend again and slowed down the process in a global scale (EPS Peaks, 2017). Nonetheless, the countries with low income have shown the highest inclination towards the use of PPP due to their budgetary constraints over the last decade.

2.4.1 PPP in Europe

England was the first country to introduce the Private Finance Initiative (PFI), a systematic program encouraging PPPs in 1992. The main objective of this program was to mitigate the public sector's borrowing requirements. However, due to some illusory effects, the next government of the country decided to expand the PFI but

this time with a more subtle focus on "value for money" (VFM) in 1997. They realized that the risk allocation must be analyzed more precisely. However, many studies proved that a remarkable number of PPP projects ran dramatically over budget and their VFM to the taxpayer was even worse than that for public financing. In England it was also observed that application of PPP for provision of schools, hospitals and some other public services is less efficient and more costly (EPS Peaks, 2017).

Table 2.4 which is presented by Button (2006) summarizes the utilization of PPP in Europe with regard to various sectors. Applicability of PPP in different sectors of different countries does not follow a similar manner. However, road projects rank first, being followed by health and education sector.

2.4.2 PPP in Australia

Application of PPPs in Australia classifies into two major groups. In the first case, private sector remunerates its investment by taking a form of availability payment from the public authority which is called "social infrastructure PPPs". In general, this type is mostly used for hospitals, prisons schools and some other types of non-income-producing infrastructures. In the second model, the private sector's revenue is related to the direct payments of service users such as tolls of the roads. These types of PPPs are called "economic infrastructure PPPs" since they are used for income-producing infrastructures such as roads railways, ports and etc.

Due to the federal system of government in Australia, applications of PPPs follow slightly different processes in different states of the country (Snelson, 2006). In early 2000s, provision of transport infrastructure under PPP framework gained popularity in Australia and some projects such as Sydney Metro Northwest, Waratah rail project and Peninsula Link Road in Victoria were constructed using PPP methods (Webb and Pulle, 2002). Afterwards, its applications expanded to other sectors particularly health and water (Snelson, 2006). However, the vast majority of PPP applications in Australia are being promoted by state sponsorship rather than the support of the central government and the states of Victoria, New South Wales and Queensland are the leading states in application of PPPs. In parallel to the Australian developments in PPP applications, the popularity of PPP has been facing an ascending order in New Zealand, too (Newberry and Pallot, 2003).

Table 2.4 : Application of PPPs in various sectors in Europe (Button, 2006).

Country	Governmental buildings	Defense	Housing	Hospitals	IT	Port	Prisons	Rail	Roads	Education	Water & wastewater
Austria				✓					✓		✓
Belgium											✓
Denmark											
Finland	✓			✓					✓	✓	
France		✓		✓			✓		✓		
Germany	✓	✓					✓		✓	✓	✓
Greece										✓	
Hungary										✓	
Ireland			✓						✓	✓	✓
Italy	✓		✓	✓		✓		✓	✓		
Netherlands	✓							✓	✓	✓	✓
Norway									✓	✓	
Portugal				✓				✓	✓		
Romania	✓				✓						✓
Spain				✓				✓	✓		
Sweden									✓		
UK	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

2.4.3 PPP in Pacific rim and South Africa

Since the beginning of the 2000s, South Africa has experienced remarkable economic progresses. Despite the mentioned economic growth, the country still faces serious infrastructure deficits in the field of transportation, power, water and wastewater, and similar facilities (Prud'Homme, 2004).

The government of South Africa is well-aware of the correlation between economic growth and higher rates of investment in the infrastructure. Thus, the country has put the item of expenditures in developing infrastructure in the first ranks of the list (Fourie and Burger, 2005). The governmental authorities in South Africa have come to the conclusion that public provision of the infrastructure is unable to suffice and fill the existing gap. To come with this inefficiency, the government has been in search of creative mechanisms such as PPPs (Kaberuka, 2011). Subsequent to the changes in the government in South Africa in 1990s, the new system took a bright view of mechanisms such as privatizations, concessions and PPPs (Burger, 2006). In 1999, the government approved of a "Strategic Framework for PPPs" and a year later a PPP unit was set up. However, some researchers believe that the number of projects being implemented under PPP framework is low which is 24 from 1998 to 2014. Indeed, in 2003 the government began a PPP programme of twenty projects in different fields of infrastructure such as transportation, health, sanitation, government buildings, prisons and wastewater (Allchorne, 2003). The most promising sign of the progressing field of PPP in South Africa was the Gautrain project in 2007 (Levinsohn and Reardon, 2007) which is a High-Speed Rail (HSR) connecting Johannesburg, Pretoria and the OR Tambo International Airport. The project's role was also absolutely highlighted during the FIFA World Cup 2010 tournament in South Africa. In accordance with this project, the private party had to design, construct, operate and maintain the service based on a 20-year PPP contract where the major responsibilities of the public partner was provision of regulatory framework, guarantees and subsidies. There are some other successful PPP transport projects in South Africa such as the Maputo Development Corridor (MDC) and N4 toll road connecting South African mines and industries to the Maputo port (Mozambique). Beside the main PPP applications in transport sector, a number of PPP projects in other fields such as health and hospital have been implemented.

The entrance of Hong Kong to the PPP market was done in 2003. Most of the PPP projects in Honk Kong are in the sector of transport and waste management (Kumaraswamy and Morris, 2002). Some chemical waste treatment plant and landfills are run by private partners whose investment remuneration are based on a fee paid by the government in proportion to waste handled. An example for PPP road project is the Tsing Ma Control Area, a highway of 16 kilometers being operated by the private sector. The payment to the public party is based on a user utilization of toll road. Another PPP application in the country is Asia World-Expo. Both public and private partners have financed the project where the management of the center is by the private side.

Just like some other developed countries, Japan faced a stagflation in 1970s and 1980s. This matter beside the shortages in public budget raised some social issues. The management in Japan was basically centralized in post war era and even earlier during Meiji period. Japanese government tended to form a decentralization and boost competition by animation of public services such as health, education, medical and the monopoly industries including but not limited to the transport facilities, power and water and participating the private partners. Japan promulgated the PFI in 1999 and since then a remarkable number of infrastructure projects in various sectors such as government buildings, schools, hospitals, waste water treatment, water supply and transport have been constructed under this framework. The leading PFI/PPP Japanese project is Central Government Building No: 7 which aims at improving the houses of the ministries of sports, science and technology, education and culture based on a 15-year BOT contract (Liu, 2010).

2.4.4 PPP in North America

Involvement of private finance in the United States was first realized in 19th century for construction of the railways. In this context, the federal government provided land using leasing methods and private partner had to construct the railway and in some cases operate it. In a similar manner, a remarkable portion of transport infrastructure in the US was provided by the private sector in early 1900s. However, following the Wall Street crash in 1929 and bankruptcy of many private firms, the participation of private partners in provision of public services and infrastructures faced a serious halt from 1930s on. During the Second World War and in Post-War

era, most infrastructures were provided by public sector and this trend continued until 1980s when Reagan Administration came to the power and revitalized the involvement of the private sector. Today, the PPP market is small compared to the giant US economy but the country has an extensive PPP program in areas of transport, water and wastewater, government buildings, prisons, schools, and etc. For instance, only in 2016, a total number of nine PPP transactions achieved financial close where the transaction costs of five of them exceeded US$ 500M (Mattei and Jacobo, 2017).

The introduction of PPP in Canada was initially done through a number of road, airport and school projects in 1990s (Allan, 1999). Siemiatycki (2015) classifies the application of PPPs in two waves in Canada: 1990-2000 and 2000-present. More than 200 PPP projects have been facilitated since its beginning in Canada. However, the most important ones are Highway 407 in Ontario, the Confederation Bridge connecting Prince Edward Island and New Brunswick, and Royal Ottawa Hospital (Siemiatycki, 2015).

2.5 PPP Pros and Cons

Similar to all other types of contracts, a PPP has its own nuance points to be regarded from very beginning of the procurement process to the end of the contractual term. It is not true and logical to consider all applied PPPs as success stories since in a remarkable number of them in a global scale, the disadvantages of the applications have casted shadows on the overall success of the project. PPPs are generally long-term agreements between public and private partners who are naturally and individually intended to protect their own interests and uncertainties over the contract term may threat the success of the process. A list of the major advantages and disadvantages of the PPPs are presented below (Loosemore and Cheung, 2015; Parvu and Voicu-Olteanu, 2009):

- PPPs ensure the required investment amount during the project's completion period.
- A better solution of infrastructure is viable by means of PPPs compared to wholly public or wholly private applications since each partner does what it does best.

- In general, PPPs deliver the facilities faster than traditional methods and delays may be reduced to a minimal level.
- If well-organized, it is possible to experience a greater Return On Investment (ROI) compared to traditional approaches specially where innovative design and financing methods are available.
- It has been observed that in many cases, all-government fulfillments have led to unrealistic expectations from the services and facilities. Within this context, private party may act as a check against the governments' unrealistic promises since the risks are fully considered in advance to evaluate the feasibility of the project.
- The lessons from the past cases have shown that the private party may be more efficient in the operation and execution phases. In PPPs, these responsibilities are mostly transferred to the private party who is best-suited to manage the mentioned risks.
- In some cases, the PPPs may include bonuses for early completion of the project where an increased efficiency may be triggered. Meanwhile, they can reduce change order costs as well.
- Governments may find opportunities to redirect their public funds and invest in other important socioeconomic areas to enhance the citizens' quality of life.
- Since the private party is responsible for the facility maintenance in most PPPs, they do their best to guarantee the quality of the system to reduce future risks and costs. This matter leads to a service with higher standards during life-cycle of the service.
- In a well-established PPP, costs reduction may result in lower taxes to be paid by the taxpayers.

However, PPPs may involve several disadvantages and include some drawbacks as follow:

- Private partners are supposed to take the risks during operation. However, they expect adequate compensations for those risks. In some cases, the

guarantees offered by the public sector to the private party may fabulously increase the governmental costs.

- PPPs may absolutely be more effective if there would be a fierce competition during the procurement process. Smaller field of bidders naturally results in less cost-effective partnering.
- Public sector may inherit some disadvantages in PPPs where the expertise is highly on the private partner.
- PPPs are not suitable for all areas and only a limited range of projects may be realized using PPP approaches. In the fields with rapid changes such as Information Technology (IT), PPPs does not work well. The application of PPPs is supposed to be more successful in the long-term and somehow predictable fields.
- PPPs include a complicated and longer process of procurement compared to other traditional approaches which makes it more costly and complex. Therefore, the project must be large enough to justify such transaction costs.
- If a foreigner private partner is selected to put the project into practice, future problems of foreign exchange may put a new risk.
- PPPs are heavily political-dependent issues and political stability is an essential parameter of a successful PPP. On one hand the government has not to present extra generosity to the private partner. On the other hand, a strong political support is a key factor of a successful PPP.
- PPPs are intrinsically inflexible contracts and they are poor at accommodating changes. By taking the evolutionary entity of the long-term PPPs into consideration, system modification would be very costly once the project has been awarded.

2.6 Risks and Risk Management

Success of a PPP project might be threatened by a number of factors or events in different stages of the project. These menacing factors which are defined as risks, may be related to the cost, time and quality of the project to be realized. Most of the risks are caused by the complexity of the arrangements between public and private

parties. In order to minimize the risks and obtain full contact with the environment of the project, it is necessary to approve organizational structure of the project fully in advance. In a study performed by Bing et al. (2005), there is a vast range of factors being involved in realization of a successful PPP. Based on this study, several factors including good governance (Badshah, 1998), governmental support (Zhang et al., 1998), project's macroeconomic environment (Dailami and Klein, 1997), appropriate administrative framework (Finnerty, 1995; Boyfield, 1992), proper financing market (Akintoye et al., 2001), existence of a good private consortium (Birnie, 1999), comprehensive cost-benefit studies (Hambros, 1999), effective risk allocation (Grant, 1996) have been considered as key issues of a successful PPP procurement.

Medda (2007) classifies PPP risks in four major groups including "technical", "commercial", "political" and "financial and economic". Technical risks account for time and cost overruns and the risks in specifying the tender. For instance, a study performed by Flyvbjerg et al. (2003) shows that actual realization costs of a transport facility may be on average 28 percent higher than the projected amount.

A remarkable portion of commercial risks are related to the existing uncertainties of the market such as changes in the traffic demand. Trujillo et al (2002) claim that the actual demand for a specific transport facility may differ from the forecasted values to the range of 20-30%.

Political risks generally encompass regulatory actions of the governments which may seriously affect the private party. Based on such risks, a concession might be even terminated one-sided. Political inconsistency of the country or radical governmental changes may severely endanger the success of a PPP project.

Economic risks may arise from economic growth uncertainties, fluctuating inflation rates, unstable exchange rates and problems related to the currency convertibility. The last issue may be more obvious for a foreigner private partner who faces local currency convertibility problems while transferring money (Balling, 1983).

Another detailed study about the PPP risks is proposed by Griffith-Jones (1993). He evaluates and analyzes the PPPs in three different phases as follows and claims that each phase has its own risks which are presented in Table 2.5:

- Promotion and preparation phase
- Construction phase
- Operation phase

Table 2.5 : Typology of PPP risks (Griffith-Jones, 1993).

Project phase	Risk	Sources of cover
Promotion and preparation	Failure of feasibility study	Improperness of the loan guarantee mechanism. Public partner might co-finance in some specific cases.
	Unsuccessful bid	High probability of an unsuitable loan guarantee mechanism
	Some legislative difficulties or mal/delayed environmental or planning	Possible candidate for insurance cover and for contractual agreements with national authorities. Loan guarantees might be involved as a complement depending on financing arrangements
Construction	Cost and time overruns	It is best covered by fixed price contracts. Performance bonds. Insurance for the technical risks
	Force majeure related delays	Insurance market
	Policy risks of changing regulations, environmental issues and etc.	Contractual agreements by regional and national authorities. Loan guarantees.
	Currency risk, fluctuations in inflation and rates of interest	Hedging arrangement alongside loan guarantees
Operating	Difficulties based on technical issues	Unsuitability of the mechanism for loan guarantee
	Excess costs and revenue shortfalls	It should be normally borne by the contractors. Some issues might be covered by concession agreement. In exceptional cases, loan guarantee may share some risks.
	Costs overruns based on changes in the regulations and policies	Loan guarantees may play a crucial role in resolution of such administrations

The major role and responsibility during the preparation phase is allocated to the government and public party. Governmental arrangements during the procurement of a PPP play a crucial role in general success of the entire process. The major

objectives of a suitable procurement are short procurement and high competition. The serious competition in a procurement ensures the public party of a minimized total costs of a PPP for the government and a short procurement paves the way for remarkable cost saving for both parties. Within this context, boosting competition, making a transparent procurement process, avoiding legislative barriers and providing a fair and clear bidding process may lead to realization of the mentioned goals. In addition, the public sector must consider subtly what exactly is required to be reached by PPP. Only the PPPs with crystal clear objectives may lead to the realization of negotiations between public side and private actors. PPP contract also require full governmental support in the preparation phase to avoid regulative delays. To recapitulate, one may advocate the fact that a successful preparation phase may only come true when there is a strong governmental engagement and unity among involved public authorities.

The major risks during construction phase of a PPP project is that the facility will not be delivered on time and on a projected budget. In general, unforeseen technical problems, uncalculated safety and security issues, inadequacy of equipment and knowledge, radical political changes in the country and conflicts among the involved parties or subcontractors may reveal problems in construction phase. To cope with these risks, an effective project management approach must be regarded and applied to minimize time and cost overruns.

Risks in operating phase mainly include commercial and political ones. In other words, erraneous forecasts and regulatory risks may affect the anticipated revenues for private party. Thus, predictability of the future revenues is a matter of paramount importance in PPPs with long construction period.

James (2017) explains that public sector tends to use PPPs in order to transfer a remarkable portion of the risks to SPV (Special Purpose Vehicle) consortiums which is remarked as first-step risk transfer. However, PPPs own sophisticated structures with complex and monolithic arrangements and entail series of risks and responsibilities and many actors may bear accountability for the management of risks. In parallel with the first-step risk transfer, it should be notices that SPVs are consortiums of multiple Joint Venture (JV) firms with distinct expertise and defined responsibilities in completion of PPPs. The risks associated with the SPV are then allocated among various JVs on multidimensional levels which is regarded as

second-step risk transfer. Thus, the risks associated with a PPP project are transferred alongside the tasks on a macro level (first-step risk transfer) from the public entity to the SPV and on a micro level (secondary risk transfer) from the SPV to the involved JVs. Figure 2.2 illustrates these macro and micro scales of risk transfer in a PPP contract. In general and in real cases, many SPVs and JVs often try to renegotiate risk allocation after the realization of an agreement and risk devolution partially takes place. Therefore, the micro level risk transfer must be monitored carefully.

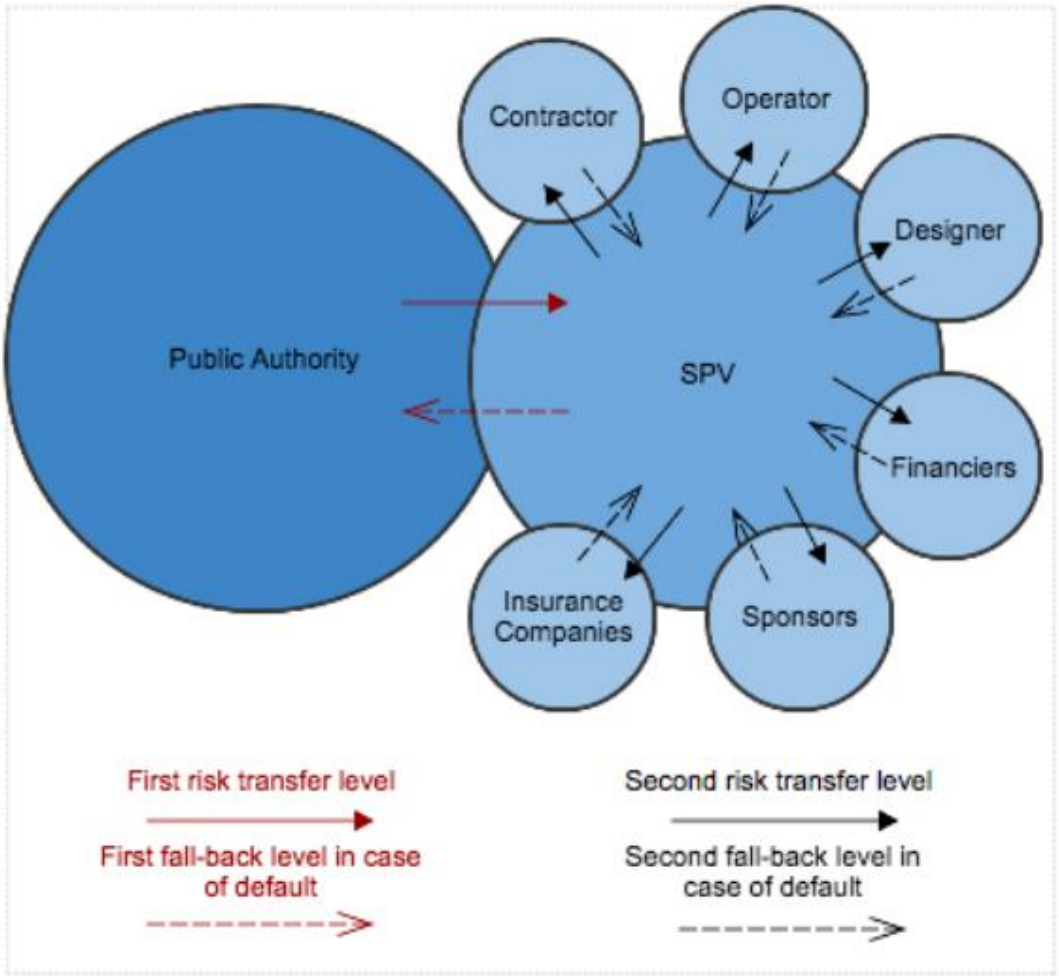

Figure 2.2 : Macro and micro risk transfers in PPPs (James, 2017).

Supervision of PPP projects requires lifecycle Project Risk Management (PRM) considerations over all actors, during all phases and assignments. Predictable risks may have known causes and measurable impacts. In particular, all PPPs contain some form of deviation from the original and initial scenario. These deviations form the bases for calculation of the impacts of the risks. Aforementioned potential deviations may include both negative (threats) and positive (opportunities) aspects. Thus, the risks own a double-sided nature and provide the project partners to earn

higher returns than expected or vice versa. Therefore, it is very important to specify which actor is supposed to be affected by probable risks.

After the identification of risks in a PPP infrastructure project, they should be assessed either quantitatively or qualitatively. De Clerk (2015) and Lam et al (2007) suggest that the former one is most common in risk assessment. Practitioners and scholars utilize computational simulation methods such as Monte Carlo method to evaluate all the probabilities associated with PPP risks. This require expertise and advances software. However, misconceptions based on humanity's error-prone and cognitive limitations may arise during the PRM process. Consequently, it is vital to incorporate the interdisciplinary input of the practitioners from both parties to develop a standard and systematic risk assessment procedure. However, in any circumstances PRM must consider the self-interest of all actors and partners. Figure 2.3 shows the pre-contractual PRM procedures. Table 2.6 clarifies the steps illustrated in Figure 2.3.

2.6.1 Risk transfer and insurance

Project Risk Management (PRM) of a PPP includes several Risk Mitigation Alternative (RMA) options as follow:

- Risk transfer
- Risk avoidance
- Risk reduction

If RMA selects transfer of risk as an optimal approach, the source of the risk, be it a public entity, SPV or JV, must ensure that the risk is allocated in an optimal manner and at a fair cost. Higher rates of VFM are conceivable for the cases in which the risks are transferred optimally. Theoretically, it is possible to evaluate all plausible RMAs for every risk of the project so that: (i) a comparison among all possible RMAs for the probable risks may be done by risk recipients and (ii) adoptation of the best RMA and optimal risk allocation can be realized. However, practically this is only viable for cases in which the risks are (i) quantifiable and (ii) able to be affected by the potential recipient of the risk. This difficulty in practical cases is related to the expensiveness and being time-consuming of the repetitive identification of risk, assessment, categorization and mitigation considerations. The processes outlined in

Figure 2.3 and Table 2.6 necessitate repeated aggregation of data before evaluation of optimal RMA.

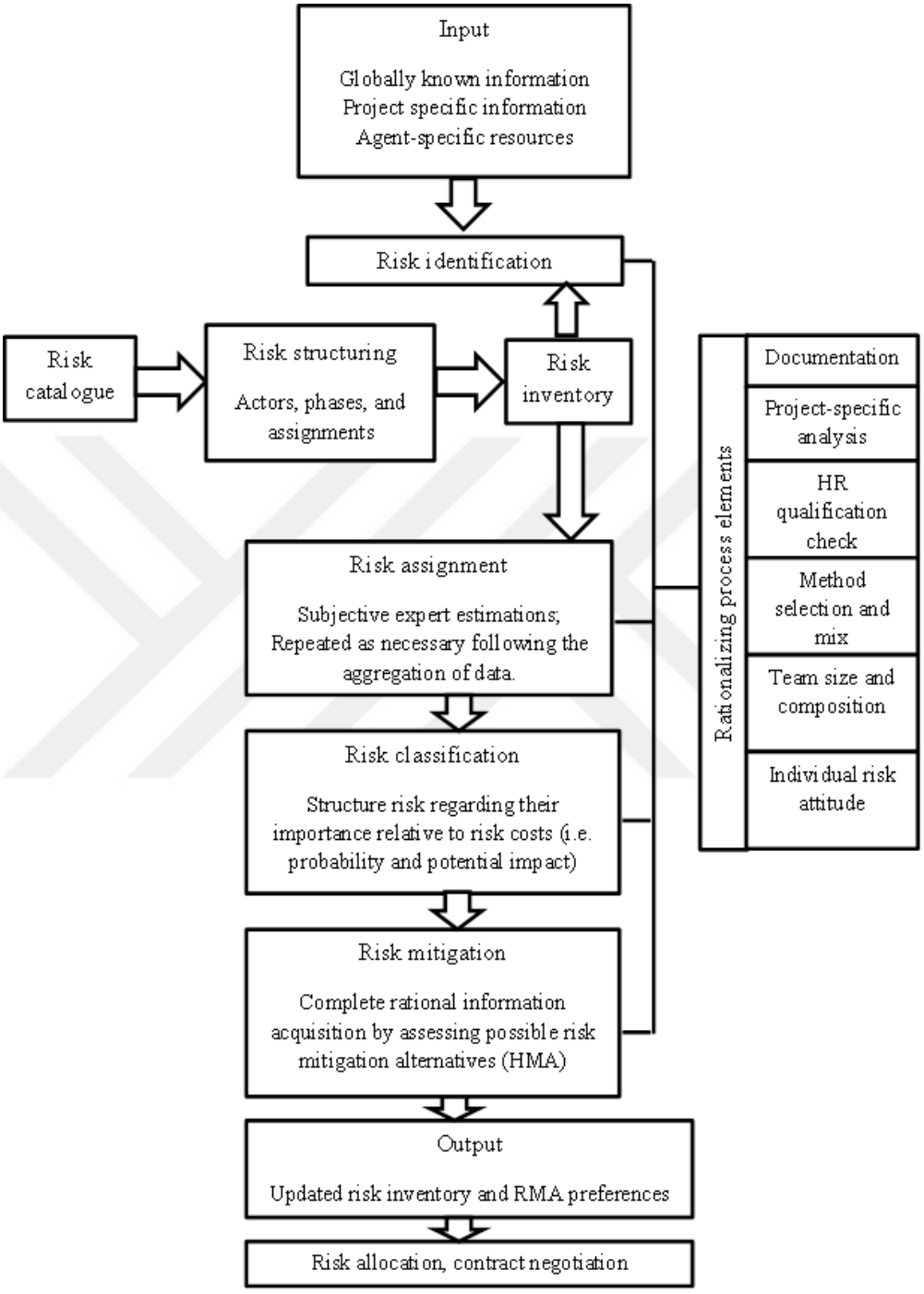

Figure 2.3 : Pre-contractual PRM cycle (De Clerk, 2015).

Table 2.6 : Clarification of pre-contractual PRM cycle.

Step	Risk identification	Risk assessment	Risk classification	Risk mitigation
Objective	Consider all plausible risks and their costs	Evaluate identified risks	Structure risks relative to their costs	Develop optimal risk mitigation and allocation options
Input	Information (i.e. global project's and agent's)	Risk inventory	Assessed risk inventory	Assessed risk inventory (aggregated)
Output	An exhaustive risk catalogue/inventory	Risk impact and probability	Potential Risk Mitigation Alternative (RMA) derived from organized risks	Optional RMA
Process	Risk structuring	Identifying risk factors: aggregate data	Methodological analyses of project risks	Methodologically identify risk mitigation factors based on risk probability/impact
Methods	Contract analysis; risk checklist	Subjective expert analysis	Impact sensitivity	Decision tree; simulation
Threats	Unidentified risks	Inaccurate risk assessment	Misinterpretation of risk severity	Inappropriate risk allocation/assessment due to strategic behaviors

It is possible to develop an optimal RMA during post-contractual PRM phases only in the case that the risk is quantifiable and risk recipients are able to influence them. Indeed, the risks which are not quantifiable may be considered as uncertainties. Selection of a predictable optimal RMA option in precontractual stages is somehow unlikely. Risk and uncertainties are distinguished since the former can be evaluated through quantitative methods such as utilization of distributive probabilities in a manner that the probability of the risk and its impacts or costs can be measured by decision-makers.

Some uncertainties are foreseeable such as occurrence of natural catastrophes and are referred to as first-degree uncertainties. Even foreseeable first-degree uncertainties may not be evaluated through post-contractual PRM since the probability of their occurrence and their potential impact on the project are not predictable. There is another type of uncertainty which is called second-degree uncertainties that remain unidentified and out of the PPP contract. PPP contracts may require immediate

mediation and legal acts when experiencing such uncertainties based on the severity of their impact.

Many scholars suggest that decision-makers insure all insurable first-degree uncertainties and risks in advance (Kunreuther, 2002). However, several insurable risks and uncertainties may be overlooked based on the public and private partners' cost-oriented approaches in practical cases. In case of insuring, risk premiums and costs of insurance are indirectly paid by public sector to SPVs throughout the payment mechanism. In subsequent level, SPVs pay the mentioned amounts to the subcontractors or project lenders via direct monetary agreements. In general, it is supposed that public sector has to retain the threats of uncertainties to a remarkable degree in PPP PRM in both scenarios: (i) the public entity solely bears the uncertainties (ii) the responsibilities are shared with private partners. For the second case, PRM should include a cap for the private party (Love et al, 2011). In sum, the public party is mainly responsible for potential threats and opportunities of uncertainties and the private partner may only share this responsibility in case it has the ability to influence the outcomes. Figure 2.4 illustrates PRM's structure of first-step risk transfer through a decision-tree.

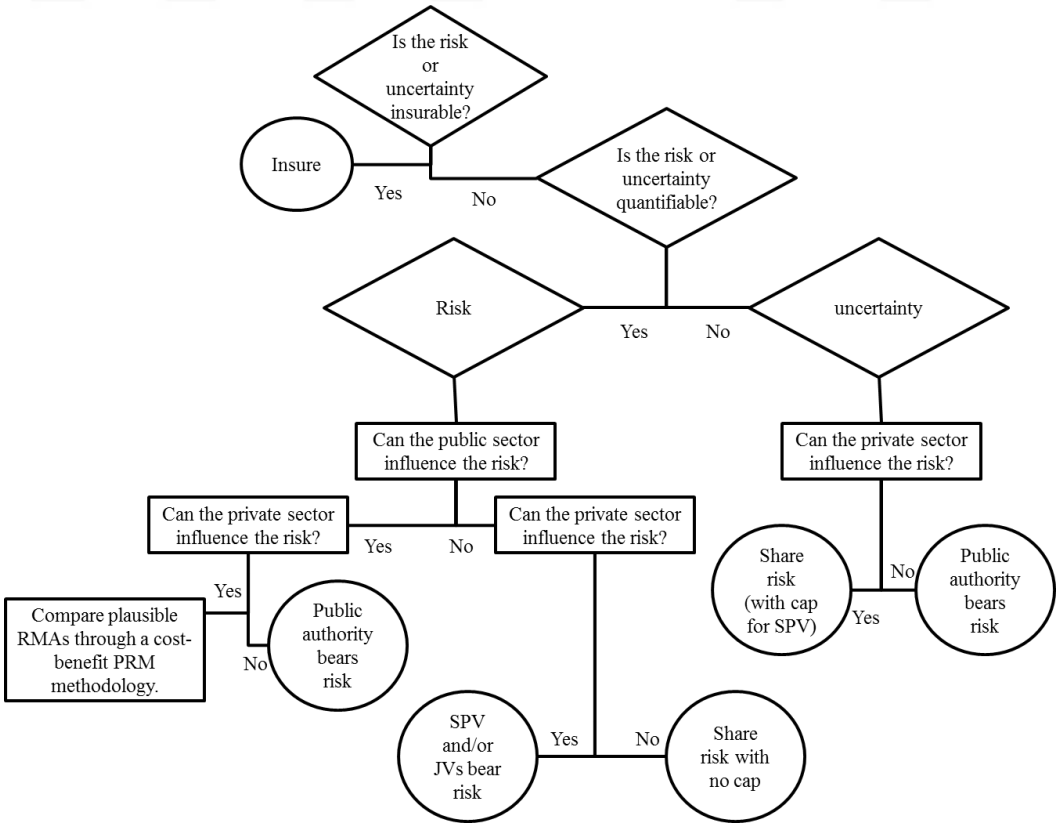

Figure 2.4 : First step risk transfer and its decision-tree (De Clerk, 2015).

The methodology presented in Figure 2.4 pursues two objectives:

- Which sector is responsible for allocation of specified risks during first-step risk transfer
- Which JVs within a SPV consortium should accept the responsibility of specific risks during second-step risk transfer

Figure 2.5 presents the final step in allocation of PPP risks in precontractual PRM.

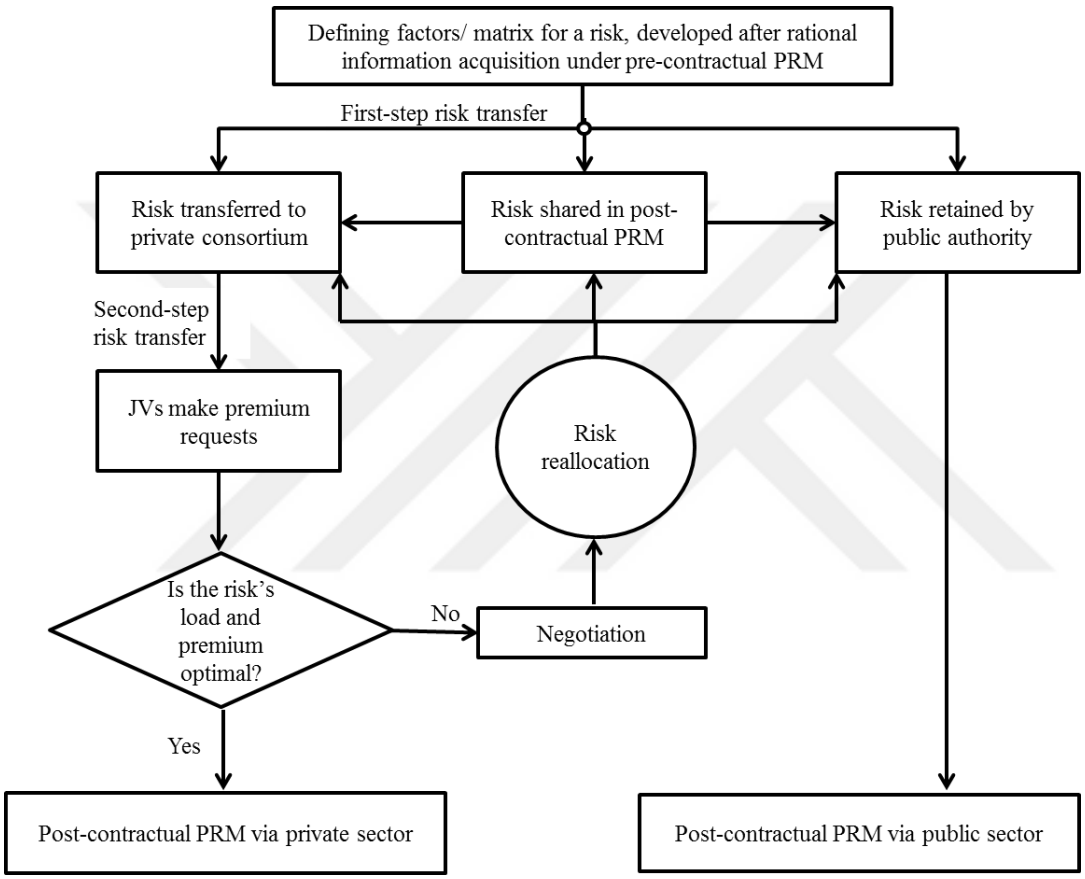

Figure 2.5: Risk allocation template for PPP PRM (Bing et al, 2005).

Public and private parties have to maintain insurance policies with regard to PPP risks. PPP contracts often provide insurance coverage in a minimum level for public and private partners and in some cases they provide a maximum amount for private partners such as applying insurable risk caps. However, it is not possible to claim that all PPP risks are insurable and it is logical to provide minimum insurance packages during PRM's earlier stages. Typically, public sector request that SPVs provide their insurance policies proposals for transferrable risks at the Request For Qualifications (RFQ) stage. The mentioned proposal in Request For Proposals (RFP) submission may include cost estimations for coverage of physical damages during

construction, delays-originated revenue losses, third-party liabilities and performance guarantees.

2.7 PPP rail projects in the world

Efficient rail transport can play a pivotal role in economic development and growth of a country by stimulating trade, connecting mines, industrial, and agricultural sites to regional and international markets, promoting the integration of different regions and facilitating a fair access to the health, education and labor markets. From the perspective of energy-efficiency, it is a well-established fact that rail transport is far more efficient compared to air and road transport and the carbon footprint of rail sector is negligible in comparison. On the other hand, HSR may be a serious alternative for long-distance air and road transport. When it comes to the freight transport, rail can be more efficient in movement of high volumes of bulk commodities. If properly designed, projected and applied, PPP can provide opportunities for rail investment with clean and high-technology operations. Shared utilization of track may also increase revenues for both public sector and private players.

Over the last three decades, more than 30 PPP rail projects have been actualized in the world (Dehornoy, 2012). However, there are many controversial views on realization of PPP rail projects. Some scholars advocate that funding and constructing mega rail projects are impossible in lack of PPP applications in a global scale. Others believe that PPP approaches in provision of rail infrastructure are more costly. They argue that PPP is a method to bypass budget limitations but at the end of the day taxpayers have to pay more and they are not economic in long-term views. In this section, a comprehensive review of rail PPPs in the world and their problematic aspects are presented. More precisely, the following issues will be outlined:

- Common features of rail PPPs
- Comparison of rail PPPs and other infrastructure PPPs
- Reasons behind the failure of some rail PPPs and need for a public support

In this study, we try to include a wide range of Rail PPPs from concessionaires with significant investment to the small-scale metro or light rail PPPs. At the first step, we will address the PPP enabling legislations in the world in the rail sector. Afterwards,

we will provide a comprehensive list of real-world rail PPPs, their features, advantages and disadvantages.

2.7.1 Laws and regulations

In case of participation of private sector in provision of a rail infrastructure, it is crucial to consider PPP-affecting regulation and laws. These regulations may deal with some important issues such as safety, technical and environmental thoughts, participation of private party, track access regimes, cross-border transportation, administrative affairs and competence of related authorities. Within this context, the following items must be studied:

- Regulations and laws related to track access
- Cross-border traffic
- Authorities
- Railway organizations

A key factor in implementation of successful PPPs is existence of a sector regulation. The main objective of regulation is to control and monitor a business by a government body or an entity appointed by it. The regulated entity may control and limitate the business in either direct or indirect manners. One may classify regulation in two branches including (i) Economic and (ii) other regulative forms. A comprehensive regulation must protect consumers against monopoly abuse, protect investors and monitor the service performance. It was previously mentioned that consumers may be adversely affected by the monopoly supplier. On the other hand, private investors tend to be aware of the changing limitations for their services, required service standards, validity of their operation license, exclusive rights, and etc. These are the matters to be regarded in PPP regulations. However, regulation should provide remarkable benefits that exceed the costs of regulating. Regulative considerations are highly recommended for liberalized markets in which the power of monopoly is extinguished. Regulations mainly follow the functions to be mentioned below:

- Tariff level settings
- Company registrations

- Monitoring operational costs
- Sector entry and exit requirements and settings
- Provision of fair competition
- Qualitative standards settings
- Safety and health considerations
- Ruling procurements
- Environmental considerations

It is better for the regulator to be independent and sector-specified regulations pave the way for more successful PPP applications. Regulation degree varies in countries with different track access regulations. In some countries, states may allow qualified private rail operators to utilize the tracks (mandated track access regime). This approach is also referred to as open-access regime. Railways of most European Union (EU) countries and those of Australia are examples of this regime. In some countries like Brazil and Mexico such regimes exist for a limited number of routes and operators. On the other hand, some countries may not follow any rail sector-specified regulation (voluntary track access regimes). In this case, the Infrastructure Provider (IP) may decide whether or not to allow a third-party access to a track. The most prominent country of this regime is United States. Table 2.7 presents some PPP rail regulative approaches from all around the world.

PPP railway projects may also aim at providing cross-border traffic. The process may involve extra challenges including but not limited to the differences in technical and regulative standards, customs and related requirements, and immigration issues. However, these problems should be overcomed by cross-border commitments and agreements in bilateral and multilateral scales between different states and/or between Private Train Service Operators (PTSO) and IPs. Interoperability of rail infrastructures, rolling stock, and technical issues such as signaling alongside of harmonizing licensing issues for cross-border railway traffic are matters of great importance.

Table 2.7 : Railway regulations in the world (World Bank Group, 2016).

Region/country	Regulation No:
Australia	Queensland Competition Authority Act 1997 Competition and Consumer Act 2010
European Union	EU Directives 91/440/EEC 95/18/EC 2001/14/EC 2004/51/EC 2007/58/EC 2012/34/EC
United Kingdom	The Railways Act 1993 The Railways Infrastructure (Access and Management) Regulations 2005
Spain	Railway Sector Act 2003 FOM 3852/2007
Germany	General Railway Law
France	Transport Code, Legislative Section- Second Part: Railway Transport, Decree No: 97-446
Peru	National Railway Code 2005
Mexico	Railroad Service Regulatory 1995 Railway service Regulations 2001
Canada	Railway Interswitching Regulations 1987(amended in 2013) Canada Transportation Act 1996 (amended in 2013)

2.7.2 Overview of the actualized rail PPPs

PPPs have been utilized to design, finance, construct, operate and maintain rail projects in four rail service types as follows (Dehornoy, 2012):

- Airport Rail Links (ARL)
- High-Speed Rail (HSR) lines
- Rolling stock and equipment
- Conventional lines

Table 2.8 makes a list of PPP rail projects from all around the world, showing their types and signing year.

Table 2.8 : List of selected rail PPPs by service type and signing year (Dehornoy, 2012).

Project	Signing year	Type	Country
Eurotunnel	1986	Conventional rail	UK, France
Orlyval	1988	ARL	France
Arlanda Express	1994	ARL	Sweden
Sydney ARL	1996	ARL	Australia
CTRL	1996	HSR	UK
Adelaide-Darwin	1997	Conventional rail	Australia
Kuala Lumpur ERL	1997	ARL	Malaysia
Taiwan HSR	1998	HSR	Taiwan
Brisbane Airtrain	1999	ARL	Australia
HSL-Zuid	2001	HSR	Netherlands
A'REX	2001	ARL	S. Korea
Perpignan-Figueres	2004	Conventional rail	France, Spain
Waratah	2006	Rolling stock/equipment	Australia
Gautrain	2006	Conventional rail	S. Africa
Barajas ARL	2006	ARL	Spain
Diabolo	2007	Conventional rail	Belgium
Delhi ARL	2008	ARL	India
Liefkenshoek	2008	Conventional rail	Belgium
GSM-R	2010	Rolling stock/equipment	Worldwide
Denver Eagle	2010	Conventional rail	USA
Poceiaro-Caia	2010	HSR	Portugal
RhonExpress	2010	ARL	France
HS1	2010	HSR	UK
SEA	2011	HSR	France
BPL	2011	HSR	France
HHR	2012	HSR	Saudi Arabia

ARL typically aims at building and operating the infrastructure alongside running and operating trains which link between airports and city centers. ARL type of rail PPPs generally run train services partly on pre-existing conventional networks (Delhi ARL is an exception). Most of the HSR projects are designed to connect with conventional rail networks on both ends (Taiwan HSR does not have this feature) and provide open access to train operators. Rail PPPs may be applied successfully in maintenance and construction of railway equipment in order to optimize the costs during lifecycle such as Global System for Mobile Communications-Railway GSM-R signaling or Waratah rolling stock. PPPs may be utilized for construction of a conventional rail service and its operation. However, they have been used in few cases and technically they are less complex. Potentially, they can add extra value based on their single-ownership structure on cross-border projects such as

Eurotunnel or Figueres-Perpignan and lack of regional expertise in the market such as Denver Eagle project or Guatrain.

While evaluating PPP rail projects, three major criteria may be used as classification parameters:

- Interfacing
- Operation
- Commercial risk

In the first criterion, it is outlined whether the PPP project is a part of a larger network and service or it is stand-alone, all included one. As for operational view, it is important to know whether the private party is responsible for design/construction of the project or for service operating, too. Last criterion differentiates between traffic-based concessions and availability-based concessions. Within this context, a PPP may follow these following trends (i) independent project vs subsystems project (ii) asset-only or integrated project and (iii) traffic-based vs availability-based project.

Practically, most of the major initial PPP rail approaches have been preferred for HSR or ARL services since they are more independent of the rest of the network . It is observed that originally most of the PPP rail projects are integrated concessions in which the private party operates train services for an agreed number of years. However, the number of asset-only rail PPPs are facing ascending order. In integrated concessions, the public party mostly undertake the commercial risk under availability-based concessions. In this case, public sector perceives revenue and makes payments to the concessionaire based on the performance. In contrast, in traffic-based concessions the concessionaire does not receive direct payment from the public party for operating the services and it receives commercial revenue on its own. Initially, most of the rail PPPs were availability-based concessions and traffic-based concessions have recently gained broader acceptance. This is mainly due to the poor record of private sector undertaking the commercial risks in traffic-based agreements. Typically, ARL PPPs mostly use traffic-based concessions where for HSR PPPs, availability-based concessions are frequently utilized.

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Rail PPPs have some specific characteristics as follows (Dehornoy, 2012):

- Most of the PPP rail projects are major technical and operational successes.
- They do not create additional resources.
- PPP rail projects do not offer better VFM than public projects.

Firstly, experiences show that rail PPPs work. Only two projects (Poceiaro-Caia and Channel Tunnel Rail Link CTRL) have not been delivered after the sign of the contract and can be referred to as failures. Although many PPP rail projects have been delivered out of their scope from time and budget views, they are being regarded as technical successes. PPP contracts are mostly signed late in the process of project design and by that time technical feasibility is no longer a menacing factor and most risks have been obviated. This is one of the reasons behind technical success of most PPP rail projects.

It is a well-established fact that railways are rarely self-sustainable in financial terms and this is true almost in every country in the world. Thus, it is not logical to suppose that PPPs will differ this manner in rail sector. PPPs are not able to create value since the only financing sources of railways are passengers/shippers and taxpayers and PPPs cannot seriously affect financial split of customer-taxpayer. In fact, PPP tends

to optimize design and management processes and reduce public debts in order to reach cost reduction. PPP only pre-finances the project which is different in essence for traffic-based and availability-based concessions. In some of the rail PPPs such as Taiwan HSR, Sydney ARL, CTRL and Eurotunnel, it was initially targeted to involve only private finance. However, none of these projects succeeded in that manner and all of them required some sort of public support such as bailout (CTRL, Sydney ARL), substantial revenue guarantee payments (Eurotunnel), project cancelation (Charles de Gaulle Express), or loan guarantee (Kuala Lumpur ERL). Ironically, public sector actually shares more than 50 percent of financing amounts in traffic-based concessions which is given in Table 2.9.

Table 2.9 : Share of public finance in some traffic-based concessions rail PPPs (Dehornoy, 2012).

Project	Percentage of public finance %
Delhi ARL	50
Perpignan-Figueres	57
Adelaide-Darwin	57
SEA	68
Sydney ARL	80
Taiwan HSR	84

Painvin et al (2010) review some risks which are specific to rail PPPs under the following titles:

- Politics
- Complexity
- Commercial

Political risks are mainly caused by lengthy processes of decision-making, execution failure, interference of other public authorities, syndrome of political entrepreneur, service acceptability by the market and public and quality of regulations. For instance, British government started to take strict safety measures after the commencement of the project during construction stage which loaded tremendous extra costs. Another example is Perpignan-Figueres project which was projected to connect two border cities in France and Spain to reduce time wasting for both freight and passenger transport. The overall success of the project was also dependent on a successful integration of the line to regional HSR line. However, Spanish

government fell behind its commitment in connection of the project to the Barcelona line for three years and caused severe losses (Majanen, 2011). Government of Portugal tended to launch an impressive HSR PPP plan but it ceased to exist due to the financial crisis and poor economy.

Complexity of rail PPPs is another issue to be analyzed carefully. This may include technical and organizational complexities. In case of the HSL ZUID PPP in the Netherlands, signaling, track and energy PPP was granted to the private sector in advance of the completion of civil works. The project experienced serious time overrun where the signaling and other technical issues were open for business by a private firm.

Commercial risks in rail PPPs are mainly related to erroneous traffic forecast. Many materialized rail projects have shown that actual and forecasted traffic would be obviously different. Flyvbjerg et al (2006) asserts that in 72% of rail projects, actual demand remains more than 40% below the forecasted value. Table 2.10 represents deviations between actualized and forecasted traffic for selected PPP rails during given time period. With regard to this shortfall in traffic demand, private sector can hardly survive. Dutzik et al (2011) propose four main reasons behind private sector's poor record at undertaking commercial risks:

- Underestimation of ramp-up period
- Unrealistic short-term expectations on profitability
- Delays in licensing issues
- Increment of ticket prices while facing ridership falls

Table 2.10 : Ridership shortfall in the selected PPP traffic-based concessions (Flyvbjerg et al, 2006).

Project	Actual vs. forecasted	Up to year (in operation for)
Arlanda Express	-25%	2005 (6)
Delhi ARL	-53%	2011 (1)
Taiwan HSR	-55%	2010 (7)
Eurotunnel	-63%	2003 (9)
Sydney ARL	-66%	2005 (6)
Brisbane Airtarin	-68%	2010 (10)
Seoul A'REX	-70%	2011 (4)
Kuala Lumpur ERL	-80%	2003 (2)

In many cases, ridership does not immediately come to its steady state after service opening. For instance, it took five years for Sydney ARL to build up a ridership and reach a steady state. In many cases, private partners tailor rosy projections and aim for the sky in initial years of the services. Some HSR projects such as HSL-Zuid and Taiwan HSR were opened half-finished and they faced delayed licensing procedures. Finally, decision-makers may decide to raise the ticket prices when facing shortages in ridership. This may potentially disaggregate existing ridership.

2.8 PPPs in Turkey

Formally, Turkey is one of the leading countries in involvement of private finance for provision of public infrastructures. Early applications of PPPs in Turkey were related to the development of power plants under the framework of Law no: 3096 which was enacted in 1984. During 2002-2018 period, Turkish economy has come through a robust growth with an average Gross Domestic Product (GDP) growth rate of around 5.5% a year (Url-2). The country has been experiencing a rapid urbanization with 23 cities of over 1M population. The population of the country is 82M with an annual growth of 1M. Similar to other developing countries, there is a big gap in development of infrastructure in Turkey. Incessantly-growing trade volume of the country and its strategic location, alongside the existing infrastructural gaps oblige the government to develop its infrastructure. By 2019, Turkey has implemented numerous PPPs in various sectors from healthcare to transportation with the worth of $139 Billion (Investing in infrastructure and PPP in Turkey, 2019). The government has created a favorable atmosphere for PPP legislations and implementations through various models such as BOT, BO, Build-Lease-Transfer (BLT) and etc. International and domestic PPP laws also protect private investments and provide international arbitration in the country by means of guaranteed purchase in most cases. Figure 2.6 summarizes the reasons behind the need for infrastructural investments in Turkey and applicability of PPPs.

2.8.1 PPP enabling legislations

As was previously mentioned, Law no: 3096 in 1984 was the first legislative framework for PPP in energy sector in Turkey. In parallel with the British PFI model of 1992 which was the first concrete step in the world in application of PPPs, Turkey

decided to enact a general law for BOT in 1994 which was Law no: 3996 in various sectors such as transportation, water supply, energy and etc. On this basis, several PPP projects (such as realization of 30 power plants) came on agenda in water supply and electricity production in 1990s under BOT and BO contracts. In Table 2.11 a list of Turkish PPP legislations and regulations is presented.

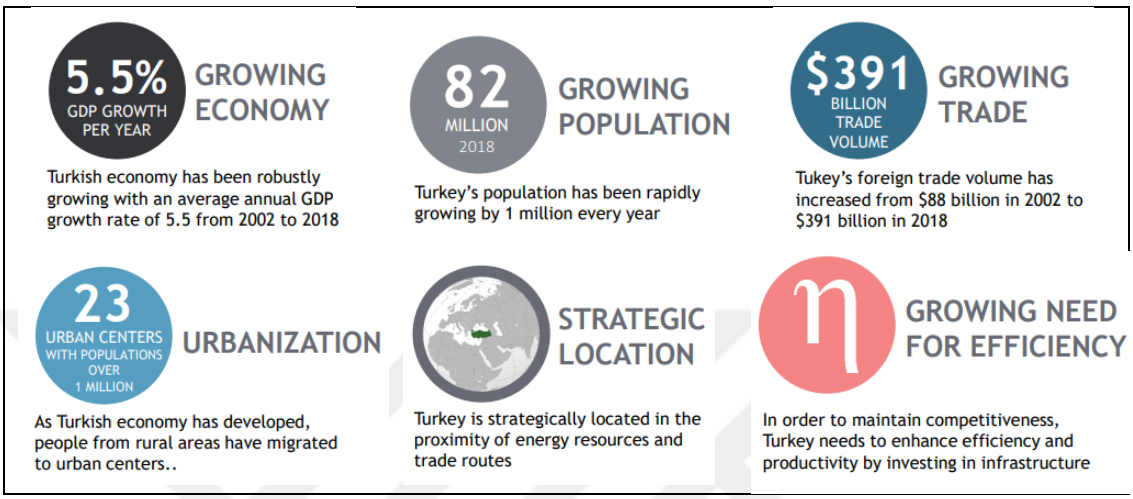

Figure 2.6: Turkey and motivations for investment in infrastructure (Url-2).

Table 2.11 : PPP enabling laws in Turkey (Investing in infrastructure & public-private partnership (PPP) in Turkey, 2019).

Scope	Law no:	Date	Explanations
BOT	3096	1984	Allowing the private involvement in the electric sector.
	3465	1988	Removing General Directorate of State Highways monopoly for construction, operation and maintenance of highways.
	3996	1994	Basic law for BOT implementations in Turkey.
BO	4283	1997	BO regulation in the sector of electricity generation.
Transfer of operational rights	4046	1994	Privatization of airports.
	5335	2005	Involvement of private sector through long-term leasing or transfer of operation rights.
	6461	2013	Liberalization of Turkish railways.
BLT	5396	2005	Involvement of private partners in construction and operation in healthcare sector.
	6428	2013	Construction, renovation and purchase of services by means of PPPs.

Despite the existence of PPP regulations in the country, a newer administrative framework is required to accelerate PPP implementations and extend their scope. So called "second generation of the PPP applications" is expected to be released late in 2019 (Investing in infrastructure and PPP in Turkey, 2019). The main items urging revisions in extant PPP models are as follows:

- There is an insufficiency in PPP definition.
- The number of PPP models are limited to a narrow range of BOT, BO and BLT.
- Scope of the legislations are limited and some important areas such as education, culture or justice are not covered in existing ones.
- Existing PPP legislations lack harmonization and sector-specific models are very rare.
- There is not any central administrative agency for PPP applications.

The new version of PPP legislations is expected to fully cover the following items:

- A broader definition of PPPs
- Unification of widespread PPP laws
- Presenting higher flexibility rates in new legislations and introducing various PPP models
- Scope extension
- Definition of the risks and risk management in a more detailed manner
- More resolute objective criteria
- Offering incentives and facilitating bankability
- Development of a central PPP structure

Two of the most important laws which are related to the railway sector in Turkey are Laws no: 3996 and 6461, where the first one may be mostly used for Greenfield applications and the second one for the Brownfield approaches.

If it is supposed to develop a new rail infrastructure in a PPP/BOT framework, Law 3996 is the major reference. With regard to this law, public agency who is

responsible for awarding the project should initially apply to the Supreme Planning Board with preliminary feasibility study. Subsequent to the official approval of the project by the government, the related public agency may tender planned BOT project. At the next step, qualified private firms have to prepare their initial proposals and bid. Afterwards, the most appropriate bid may be selected and the public agency awards the private firm whose bid is compatible with the priorities of the project in a multidimensional manner (Shakibaei and Alpkokin, 2017). International investors are also encouraged to participate in development of such infrastructures in Turkey and the Law no: 4875, Foreign Direct Investment Law, which is in force since 2003 constitutes legal frame for foreign investment. This law provides equal rights and incentives for international investors and guarantees that foreign capital is being treated like national one. Finally, the Supreme Planning Board evaluates the risks and the way they might be transferred to the private partner in a detailed manner. The board also urges related public authorities to officially announce the project well in advance (at least 1 month before the closure of initial application) to ensure a fair competition and transparency. The maximum allowed time to private party for the concession/operation is 49 years and at the end of the contractual time, the asset will be transferred to the government. However, there is not any actualized PPP rail project in the country to date. According to the law, the government is responsible for land expropriation but these costs must be borne by private party. The laws give the rights of land utilization for the private sector for 49 years and at the end of the period, the lands and property rights pass into public sector's hands.

On the other hand, newer Law 6461 aims at liberalizing the Turkish State Railways (TCDD). The law which is in force since May 2013 offers open access in the rail network of the country and encourages private party to invest in the sector. Long-standing monopoly of the state (TCDD) in Turkish rail sector was abolished using this new law. Following this objective, two separate entities with distinctive purposes called National Railway Institution (NRI) and a joint stock company, TCDD, are established. NRI stands as a government institution and regulates operation/maintenance of railways and construction of HSR lines and TCDD acts as a transportation company.

Herewith, NRI is the provider of the infrastructure and stands on behalf of the State. Under new regulation, NRI is responsible for both network management and

maintenance of the network. Besides, NRI is the authorized organization for development of new HSR lines. In a new open market, NRI has to ensure that all PTSOs including TCDD have access to the same conditions and a fair competition is available. As NRI still takes the responsibility of maintenance for existing network, Law 6461 is not supposed to privatize the current railways. However, future revisions may also cover privatization processes. In the new environment, TCDD is regarded only as a operating company and has to compete fairly with the rival PTSOs under the same conditions in the open access market. Thus, there will be no distinction between TCDD and others in terms of legal status. In other words, NRI is the regulatory government body and TCDD is a private firm being subject to the regulations of the Turkish Commercial Code and NRI.

In new market, PTSOs may set up their own companies by either providing services on the existing railways which is presented by the public sector or on the lines which are constructed by private sector's capital. In the second case, PTSOs have to pay the usage fees to the private infrastructure providers. However, all PTSOs whom have been granted operation license by the Ministry of Transport, Maritime Affairs and Communications should be exactly considered under the same payment regimes and there would be no payment privileges for some particular firms.

2.8.2 Turkish experience with PPP projects

Infrastructure capacity in Turkey lags significantly behind that of developed countries and Turkey strives to set ambitious targets to upgrade its infrastructure and keep the pace with developed economies. To attain these aims, financial and technical participation of private sector is somehow inevitable and PPP applications have been the focus of attention in recent decades. In Turkey, PPPs are mostly implemented in energy, transportation and healthcare sector to date. Figure 2.7 shows the number of Turkish PPP projects and their values. Sector-specified breakdown of the PPPs is also given in Figure 2.8 and Figure 2.9.

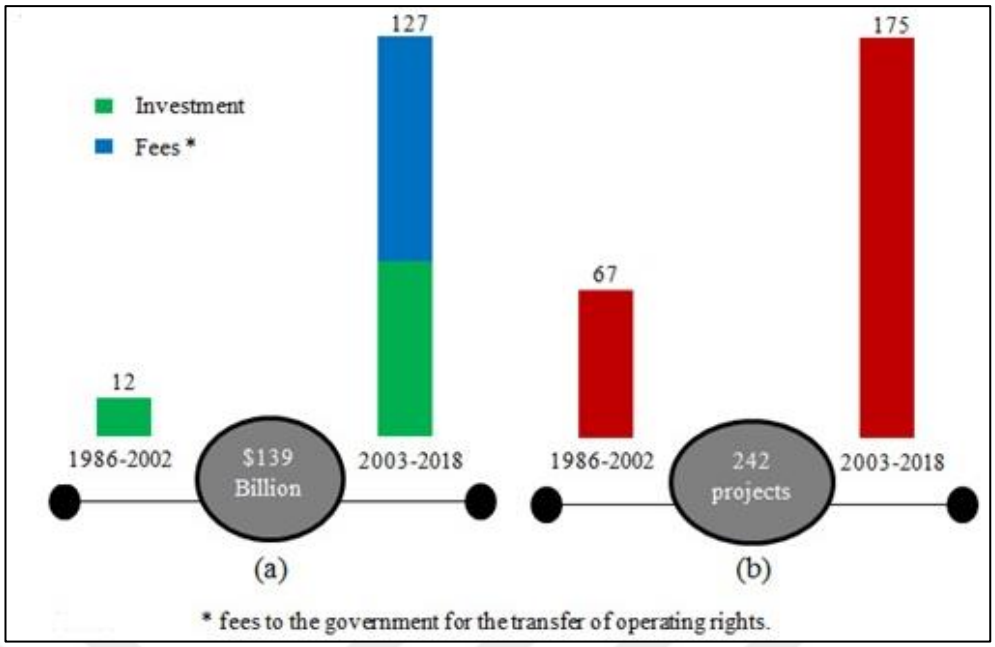

Figure 2.7 : PPP projects in Turkey, (a) in $ Billion (b) number of projects (Investing in infrastructure and PPP in Turkey, 2019).

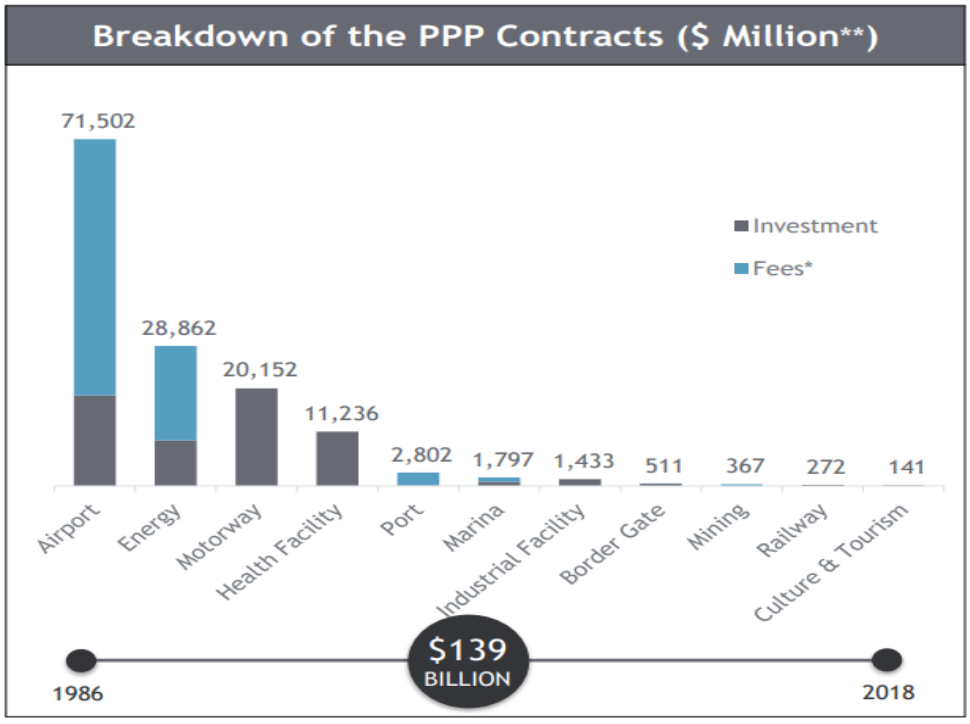

Figure 2.8 : Sector-specified breakdown of PPPs in Turkey and the values (Investing in infrastructure and PPP in Turkey, 2019).

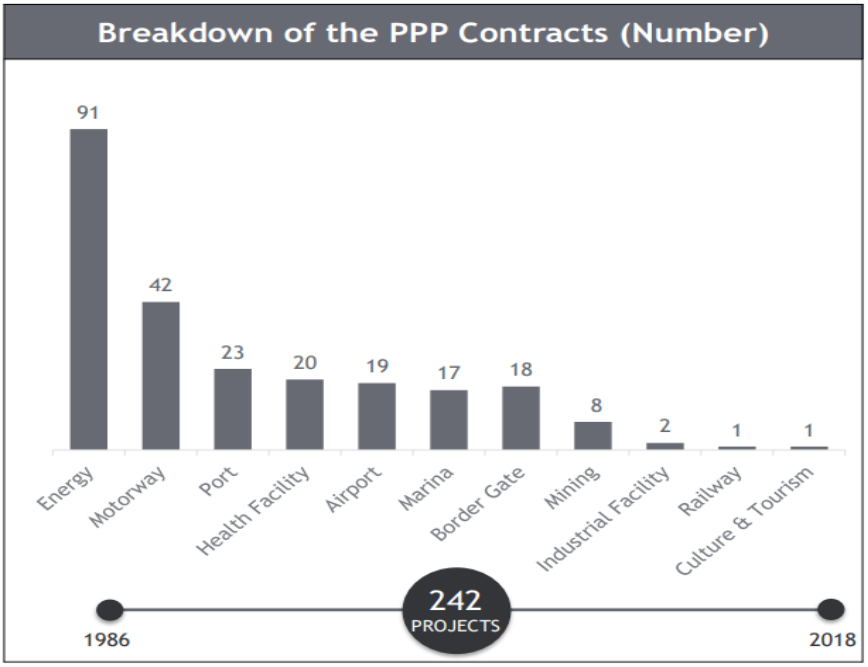

Figure 2.9 : Number of PPP projects based on their sector-specification (Investing in infrastructure and PPP in Turkey, 2019).

Figure 2.10 and Figure 2.11 show the PPP models for aforementioned projects in Turkey. Figure 2.12 to Figure 2.15 show the infrastructural reformation of Turkey in the last two decades and targeted 2023 and 2035 perspectives in railway, highway, healthcare centers and power plants, respectively (Investing in infrastructure and PPP in Turkey, 2019).

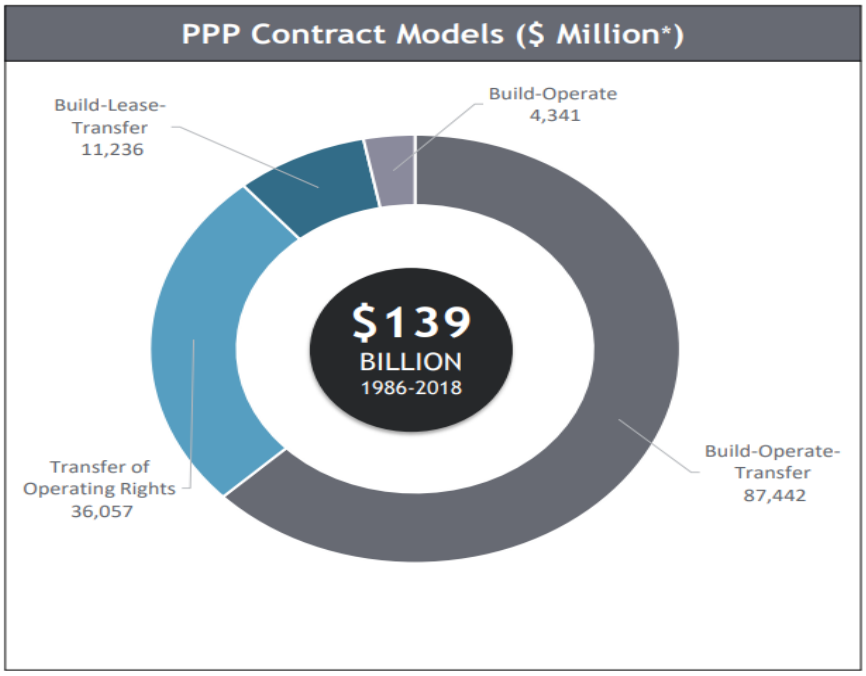

Figure 2.10 : Implemented PPP contract models in Turkey (Investing in infrastructure and PPP in Turkey, 2019).

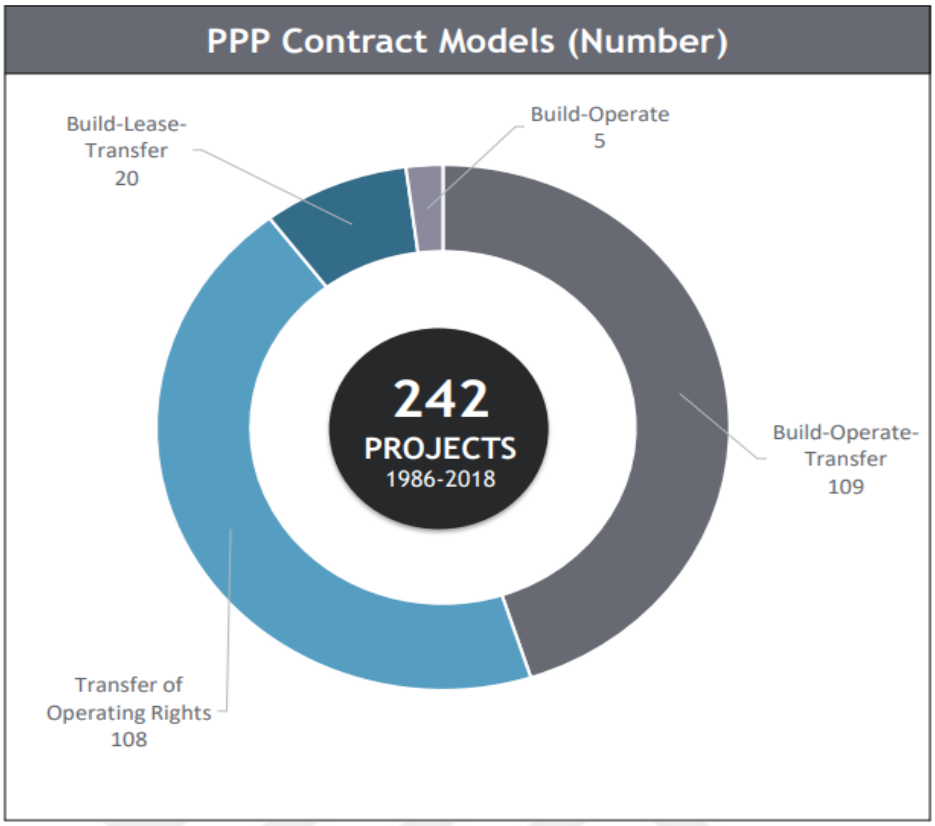

Figure 2.11 : Number of applied PPPs in Turkey based on their contract type (Investing in infrastructure and PPP in Turkey, 2019).

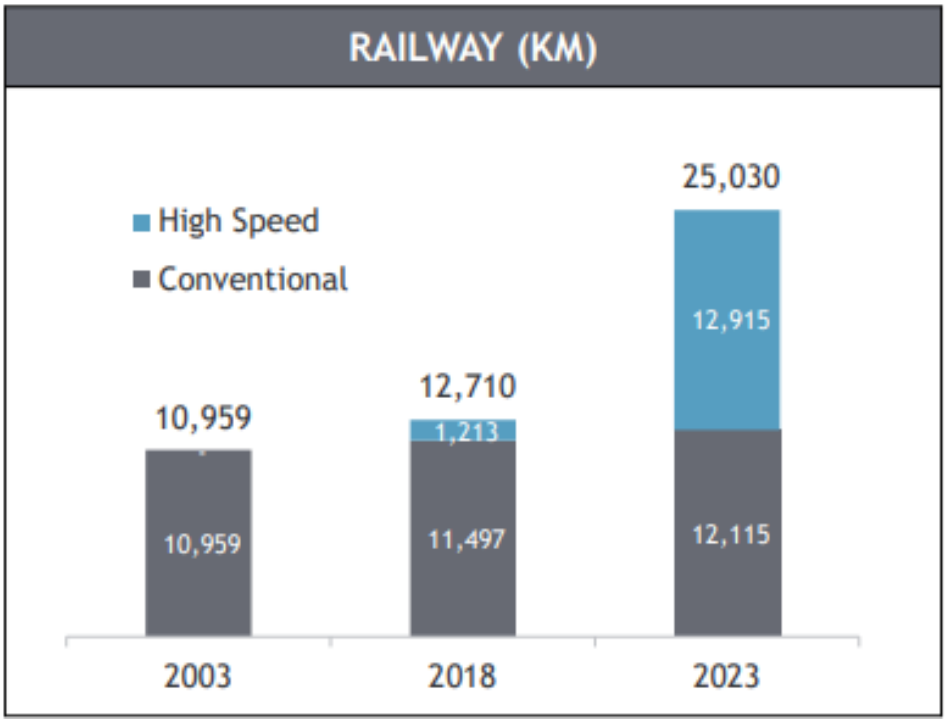

Figure 2.12 : Past, present, and future outlook of Turkey in the rail sector(Investing in infrastructure and PPP in Turkey, 2019).

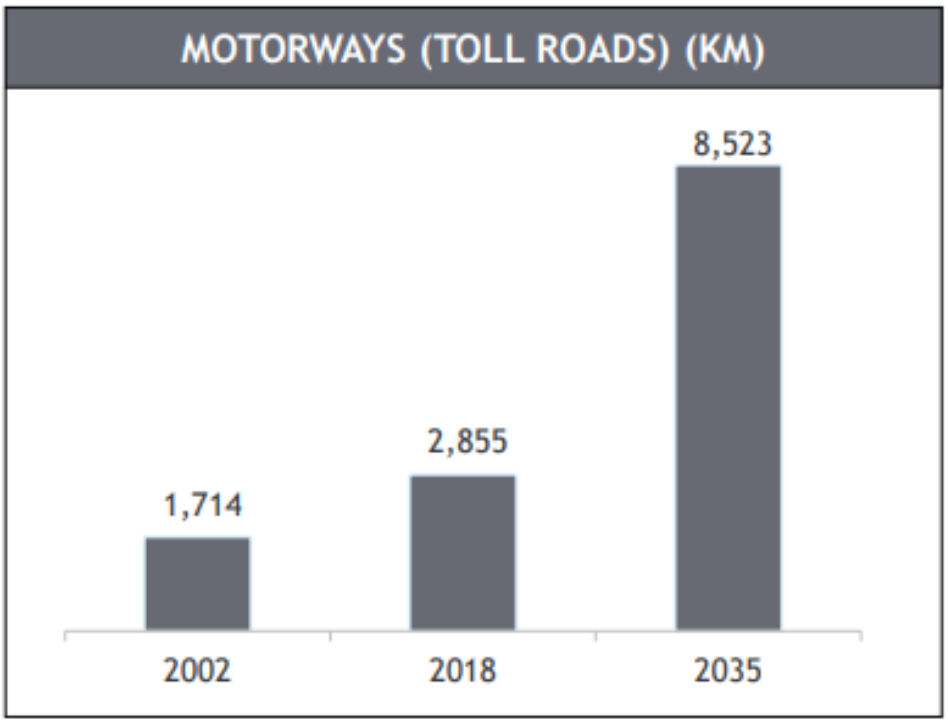

Figure 2.13 : Expansion of the highways in last two decades and future outlook (Investing in infrastructure and PPP in Turkey, 2019).

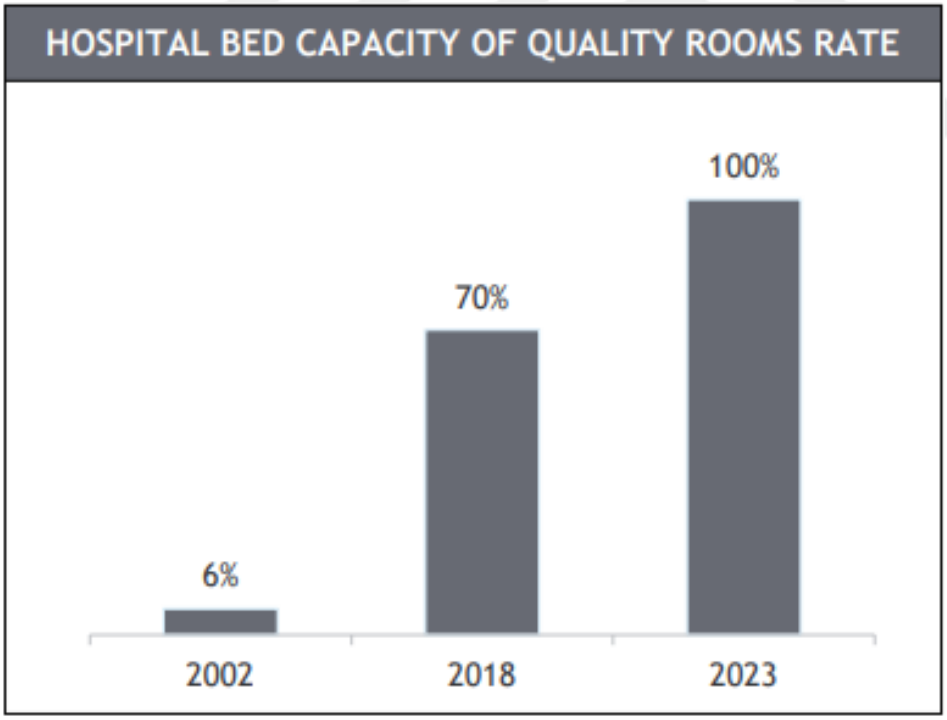

Figure 2.14 : Improvement of the healthcare centers since early 2000s (Investing in infrastructure and PPP in Turkey, 2019).

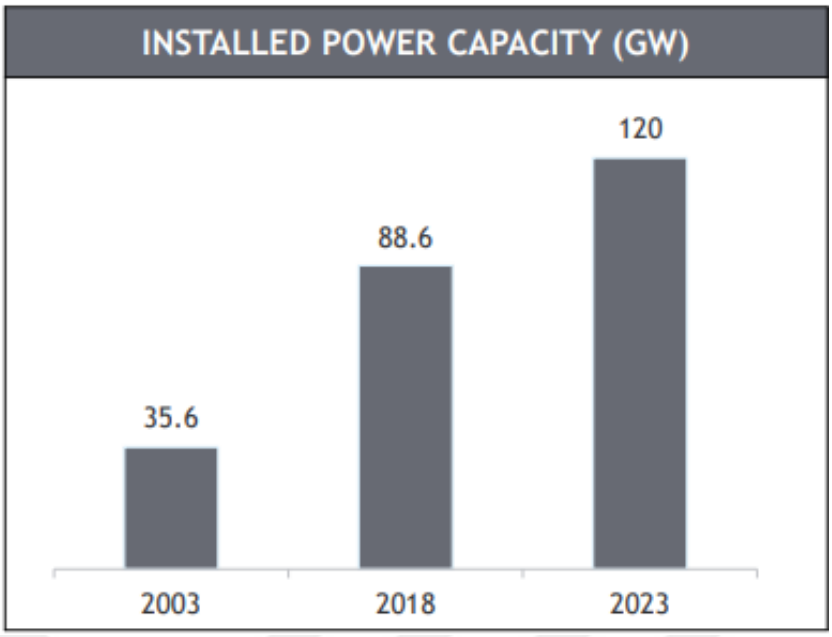

Figure 2.15 : Increment of the energy capacity during last two decades (Investing in infrastructure and PPP in Turkey, 2019).

At this stage, a detailed presentation of PPPs in transportation, health, and energy sector is given. Subsequently, strength and weak points of these applications will be presented. Table 2.12 summarizes PPP healthcare projects in Turkey. In essence, the "City Hospitals" aim to actualize health transformation, offer quality health services at shortest time span, animate health tourism and attract foreign patients. However, the opposition in Turkey criticizes the success of these targets with regard to their patient guarantees and related extra expenses for those who even do not get the services. On the other hand, some critics believe that increment in access to these health centers has not positively affect the quality of services.

Table 2.12 : PPP healthcare projects in Turkey (Investing in infrastructure and PPP in Turkey, 2019).

Status	Number	Bed capacity
Completed (in service)	9	12062
Under construction	12	18747
In tender process	10	12300
Planned	1	1200
Total	32	44309

As for transportation sector, a number of mega projects have been put into service mostly in the area of highways and airports. Table 2.13 summarizes some of the most important PPP transport projects in the country. Figure 2.16 and Figure 2.17 show the investments in transport sector and the share of PPPs in the market, respectively.

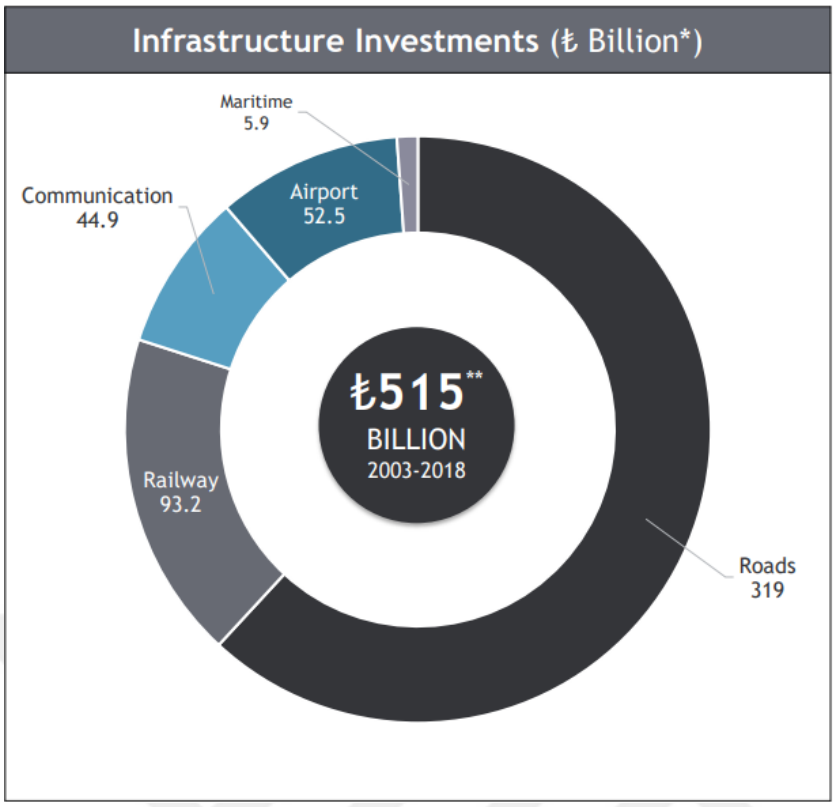

Figure 2.16 : Investment in transportation infrastructure in Turkey (Url-3).

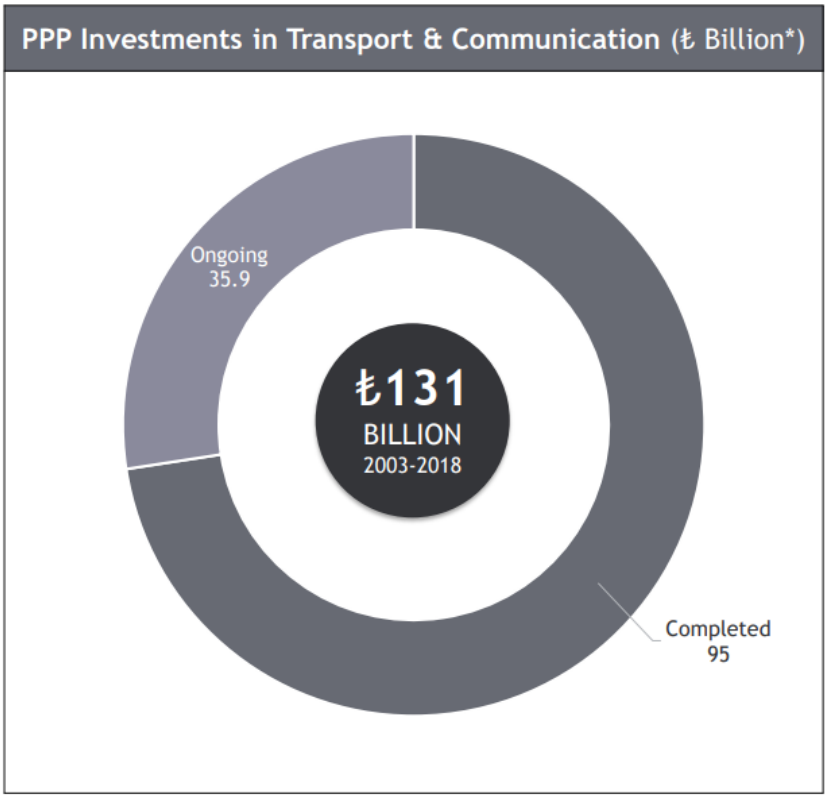

Figure 2.17 : Share of PPPs in transport infrastructure investment (Url-3).

Table 2.13 : Selected PPP transport projects in Turkey (Url-3).

Project	Investment cost	Explanations
Istanbul North Marmara Motorway	$ 3 Billion	BOT. Including 3rd Bosporus Bridge. 102 km motorway and total of 158 km. construction period of 2.5 years for the bridge and total of 4 years for connections. Operation by private partner 10 years 3 months.
Istanbul Eurasia Tunnel	$ 1.4 Billion	BOT. 20 km including 5.5 km of the tunnel. 4.5 years of construction period. Operation by private partner for 25 years.
Gebze-Orhangazi-Izmir Motorway	$ 7 Billion	BOT. 433 km of highway. Includes Osmangazi Bridge. Operation period by private partner 15 years 4 months.
Istanbul New Airport	$ 14.4 Billion	One of the biggest airports in the world, targeting 150 Million passenger capacity per year. Including 4 phases where the first one is in service since 2018. Construction period of first phase is 42 months. Operation by private partner 25 years. Lease amount $ 1.5 Billion per year including VAT.
Ankara-Nigde Motorway	$ 1.14 Billion	330 km of highway.
Kinali-Tekirdag-Canakkale Motorway	$ 2.9 Billion	324 km of highway.

Figures 2.18 and 2.19 illustrate the projected HSR and highways in Turkey, respectively. The figures show the importance of participation of private party in provision of such infrastructures.

These projects make the passengers' path shorter and result in remarkable time and fuel cost savings for them. They may also reduce carbon footprint since they are environment-friendly considerations. The risks of accidents and related deaths may seriously fall.

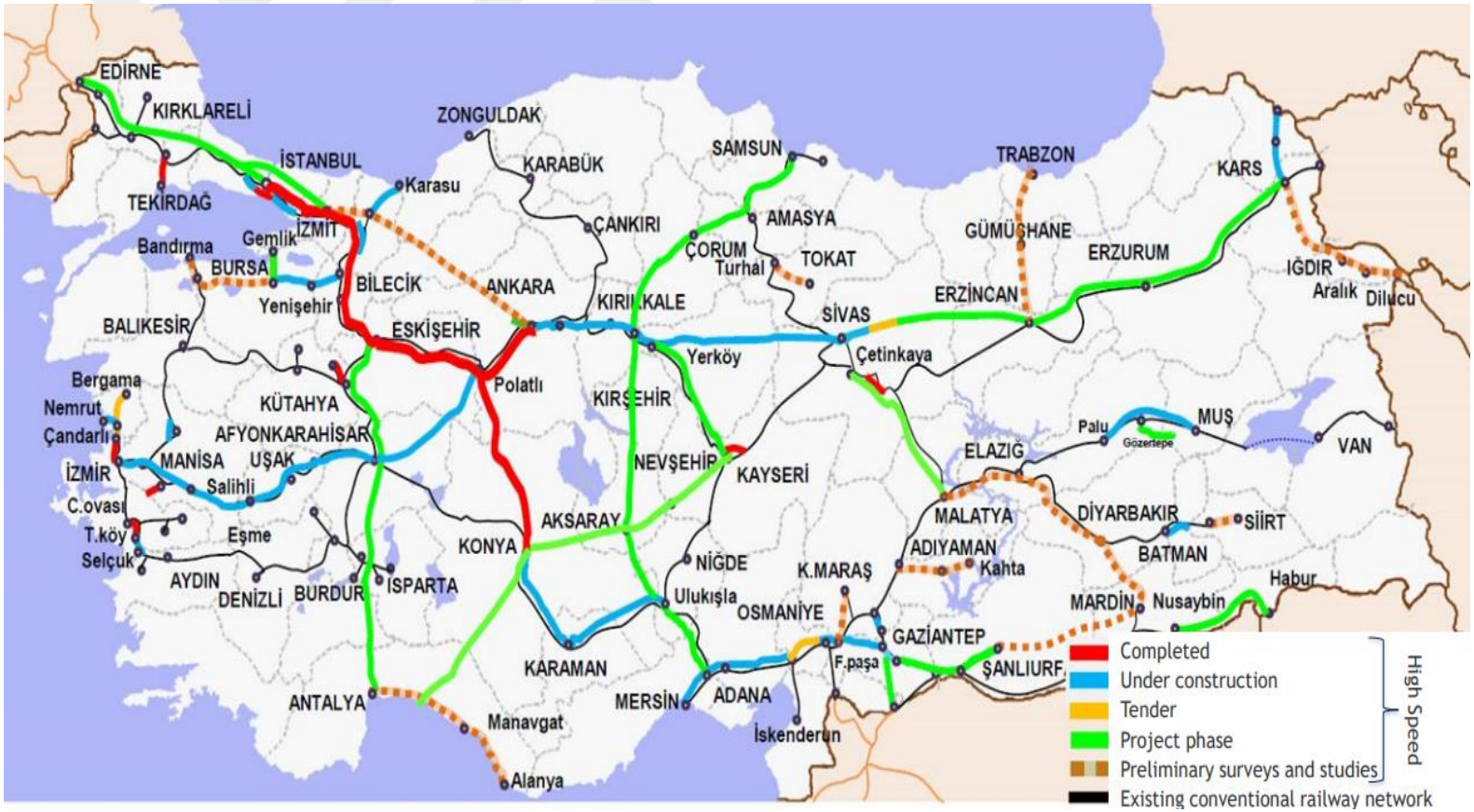

Figure 2.18 : Turkish map of High-Speed Rail (HSR) network (Investing in infrastructure and PPP in Turkey, 2019).

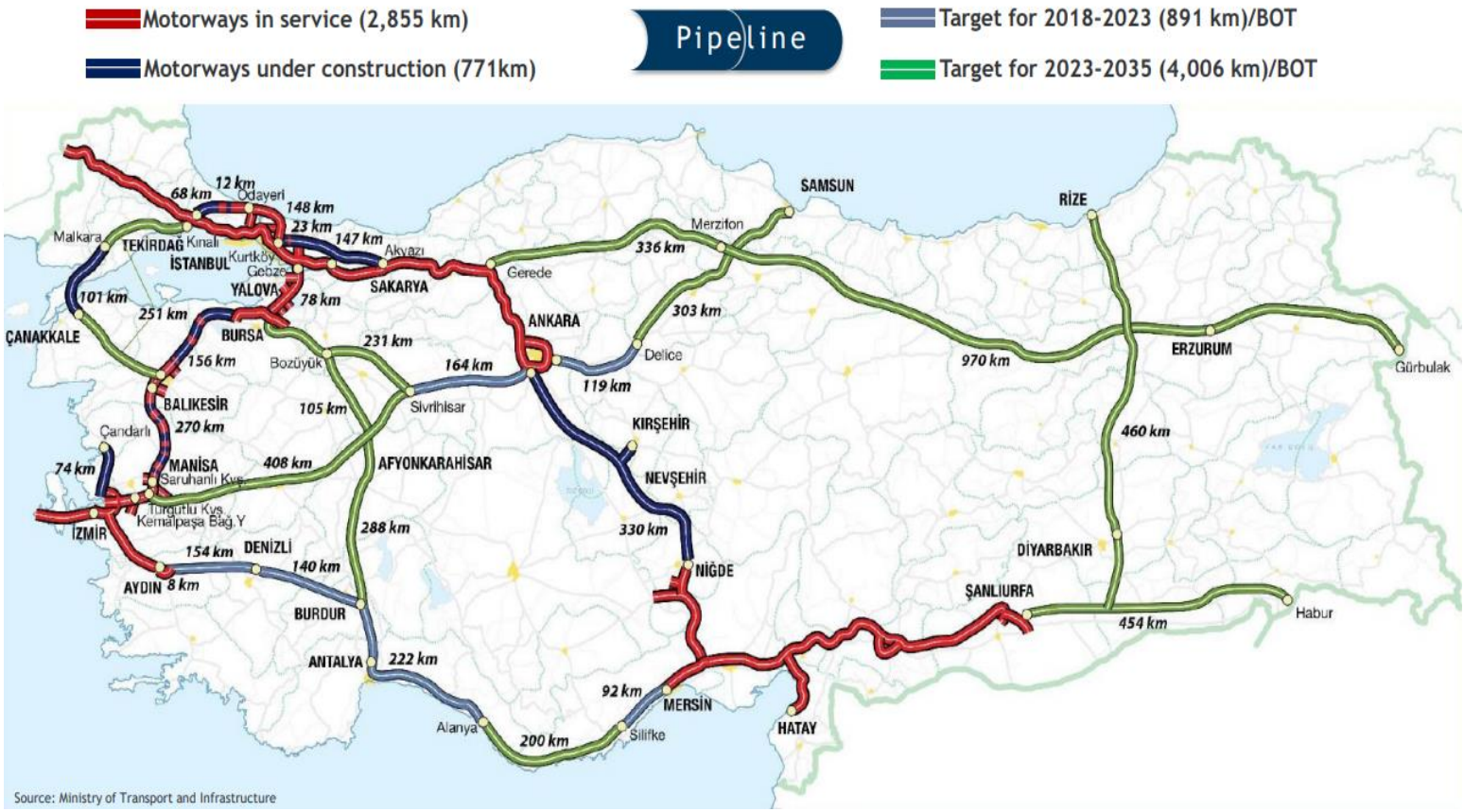

Figure 2.19 : Turkish map of highways (Investing in infrastructure and PPP in Turkey, 2019).

However, in most cases, traffic guarantees given to the private investors by the public entity challenge the overall success of the projects. On the other hand, the fact that the contracts and guarantees are generally based on foreign currencies endanger the sustainability of such projects, particularly due to 2015-2018 remarkable fluctuations in exchange rates in the country.

At this step, to recapitulate and get favorable results, the parameters which should be considered to succeed in realization of PPP projects for both public and private partners are listed.

Private sector has to evaluate following items:

- Political stability of the country
- Political willingness to apply PPPs
- Existence of proper regulatory environment
- Economic stability of the country
- Existence of reliable conflict resolution mechanism
- Existence of powerful governmental organizations

On the other side, public sector should analyze the following items in detail:

- A comprehensive understanding of PPP and its scope
- Prioritization of the projects based on their value and sectoral importance
- Preparation of a detailed and realistic feasibility study
- Preparation of a VFM analysis
- Proper risk allocation between public and private partners
- Realistic estimation of liabilities such as demand guarantees, revenues and debts
- Putting all related public institutions in proper accordance
- A logical process of bidding
- Proper contract management
- Making use of technical and financial consultancies whenever needed

- Strict inspection and transparent evaluation of performance
- Creation of a systematic data flow among various institutions and PPP unit

2.9 Rail Market Liberalization in Europe

European rail companies were experiencing the peak of ridership loss in the 1980s and they were highly dependent on public support. Accordingly, European governments were under pressure to find alternative solutions to dilute fears about rail networks' tremendous national subsidies (Alexandersson and Hulten, 2008). Sweden was the first country to perform the market liberalization in 1988 by adopting the Transport Policy Act (Nilsson et al, 2013). The first market entrance by means of this reform took place in 1990 which resulted in allocation of lower public subsidies and reduction of prices in regional lines. Successful developments in Sweden caused by separation of the infrastructure provision and service operations and related competition boost persuaded European authorities to apply similar regulatory framework in an EU-wide scale. The major objectives of such a framework were liberalization of national railways and integration of cross-border networks.

In this chapter, liberalization, privatization and marketization of the sector will be presented. Besides, a brief historical outline of the railways and reforms in Europe will be given. Finally, various liberalizing approaches in different European countries and their effectiveness will be analyzed.

2.9.1 Liberalization, privatization and marketization

At the beginning of the evaluation of the liberalization and marketization terms, a presentation of depictive abstract is required.

"Liberalization" is an economic term implying the relaxation in the field of legal restrictions and/or state provisions on public services such as transportation facilities, energy plants and etc. In most cases, public assets' ownership is transferred to the private party. The old regulations of the European railways had made the state monopolies the only legal provider of the infrastructures and train operating centers. Thus, liberalization and deregulation often stand for enabling competition and providing open access for private partners in the sector.

Rail investments are mostly large sunken cost and investors may request monopolistic rights. On the other hand, if it is supposed to provide transport facilities by international private partners which is called “cabotage”, a broader sense of considerations is required. Therefore, a prerequisite condition for liberalization is the separation of rail network management from train operations. Thus, it is rational to define different degrees of liberalization as follows (from least to most) (Bros, 2015):

- Single vertically integrated company
- Bookkeeping separation
- Organizational separation
- Institutional separation

Competition in the liberalized market is a key issue. The degree of competition in new market may also vary widely as below (from least to most):

- Monopoly
- Yardstick
- Franchising
- Open access

In markets where private rail companies do not have adequate incentives to improve productivity, a yardstick competition dominates. These kinds of markets may theoretically cover deregulations. However, realization of a fair competition is relatively impossible in practical cases and there would be no-to-weak competition. Within this regulative framework, public authorities reimburse private partners based on their relative performance. This type of reward mechanism may induce a competitive process among the private agencies but favor one private firm. In early definitions of yardstick competition. The term was used for the cases in which a state-owned company had to compete with other private partners. This state-owned firm would be regarded as the yardstick or benchmark.

Another dimension of liberalization binding is franchising. UK is a leading country in application of this method since mid-1990s. The process includes the franchisor as owner of the infrastructure and assets and the franchisee who is operating train services awarded by public sector based on a contract and in pursuit of a competitive

tendering process. The best example of franchising system in transport sector in EU is the sector of civil aviation. In this sector, an established owner of the airports provides the infrastructure and licensed airways act as service providers.

Privatization is another branch of liberalization where the ownership of the asset is transferred to the private party from the public sector. Despite the fact that liberalization and privatization are often being mentioned hand in hand, these are distinct concepts, as well.

Open-access market or marketization process involve the restructuring procedure in which the planning, delivery and finance of the services are to be borne by private party. Which were formerly done by state-owned entities. The process totally changes the legal environment of the sector. Commodification of the infrastructure and services, boosting competition, reorganization of work, productivity maximization and rights transferability are the major elements of marketization process.

2.9.2 European railways' regulative framework

From the early beginnings of the European railways, repetitive reforms have been applied in different stages. The final trend encompasses the market opening (liberalization) and privatization (franchising). In this section, we try to present the gradual liberalization of the European railways beginning from mid-20th century.

As discussed above, European railways suffered from unprofitable services, inefficient management and commercial outlook for much of the 20th century. These parameters gave incentives to European Union Member States (EUMS) to perform reformations on their national railways throughout the packages of the European Commission. These reforms pursue a number of inclusive goals as follows:

- Sustainable financing thorough reduction of the need for public subsidies
- Efficiency and productivity enhancements by means of market opening
- Boosting competition by separating operations from infrastructure provision
- Introducing independent regulation authorities
- Interoperability

- Integration of national rail networks to a single unit of European railway realm

The foremost step in European railways liberalization was EU Directive 91/440. The philosophy behind this directive was to establish distinct organizations for infrastructure provision and service operations. The directive was mainly aiming at performing a neutral fashion in providing a fair access of the track for newcomers (European Commission, 2008).

In 1995 and subsequent to the EUMS's major efforts in unbundling infrastructure management and operations, two newer regulations were presented to concentrate on licensing and infrastructure allocation. A universal licensing process was presented by Directive 95/18/EC where qualified and licensed PTSOs would obtain rights to operate on the network. Besides, such licensed firm which has obtained the license from one EUMS could fairly compete with other private firms and operate services in all other member countries. Second part of the Directive, 95/19/EC, provided a fair capacity charging and track allocation for PTSOs. These two Directives re-enforced Directive 95/18/EC, without whom the initial reform was ineffective.

A newer version of the aforementioned directives came into effect in 2001 in three parts. The first part, Directive 2001/12/EC, extended the vertical separation of Directive 95/18/EC in a clearer manner. Directive 2001/13/EC inserted stricter licensing requirements particularly for safety and service quality issues. Directive 2001/14/EC focused on providing non-discriminatory allocation and infrastructural charging. It introduced an independent entity to set the access fees and further limitated the monopolistic power (European Commission, 2010). The first directive to enact legislations to minimize delays in cross-border transportation at borders was the Directive 2001.

Next generation of EU directives released in 2004 with a further concentration on interoperability and upgrading safety. Directive 2004/49/EC aimed at harmonizing safety issues for new PTSOs and boosting international operations. Interoperability was also highlighted in Directive 2004/50/EC throughout developing international HSR services. Directive 2004/51/EC introduced liberalization for freight transport market and opened up both cross-border and domestic cargo.

The third package improved market liberalization by allowing free access to the international passenger market via Directive 2007/58/EC. Subsequently, Regulation 1371/2007 provided a EU-wide enhancement of rights for passengers. Directive 2007/58/EC also increased the interoperability of Trans-European rail network.

As of January 2013, the fourth package was proposed to add rolling stock authorization and cut administrative costs for the approval of rolling stock.

To recapitulate the process in some key EU member countries it can be noted that the Swedish act of 1988 transferred the network to Banverket which is the national rail administration. In 1996, freight operations were liberalized; In 2000, operations of passenger transport was transferred to SJ, (another government-owned train operator). Fixed assets such as stations became the control area of the Jernhusen, a government enterprise in 2001. Passenger services fully changed to be in an open access market since 2012. All PTSOs have to pay Track Access Charges (TAC) to Trafikverket, Swedish Transport Administration since its opening in 2010.

Table 2.14 shows the time of vertical separation in different EU countries which are derived from a study conducted by Friebel et al (2010).

Table 2.14 : Vertical separation time in EU railways (Friebel et al, 2010).

Country	Vertical separation year
Sweden	1988
UK	1993
Germany	1994
Finland	1995
The Netherlands	1995
Spain	1996
Austria	1997
France	1997
Portugal	1997
Denmark	1997
Italy	1998
Belgium	1998

The progresses in Sweden was followed by the UK in 1993 by the Railways Act of 49. The act targeted gradual privatization for the 1994-1997 period to limitate the British Rail monopoly. To do this, passenger services were franchised by qualified PTSOs via a competitive process of tendering. The infrastructure was controlled by a group of private firms, Railtrack, until they went bankrupt in 2002 and transferred it to the Network Rail, a non-profit state-owned company.

Germany started fundamental reformations in rail sector in 1994 and gradually provided open access market. Both railways of East and West-Germany consolidated and formed Deutsche Bahn (DB). DB has the structure of a government-held holding company but is being managed by semi-autonomous divisions for the infrastructure, passenger services and freight. Beside the DB, Eisenbahn-Bundesamt (Federal Railway Office) which is a government body authorizes and inspects rolling stock companies and most of the domestic infrastructure.

In 1997, France started to separate its rail infrastructures from SNCF, the state-owned company. Furthermore, a new state-owned company, RFF was established to own and maintain the national network. However, the separation remained unfulfilled since SNCF kept all French train stations' ownership and took over all maintenance responsibilities of RFF.

To sum up, we can observe that EU countries have followed three common rail liberalization trends as follows:

- Complete separation (such as Swedish model or British franchising method)
- Holding company (German version of the liberalization)
- Hybrid model (like French approach)

The level of rail liberalization in European countries is evaluated in a research by Kirchner (2011) where he introduces an explanatory variable, COM which is given in Table 2.15.

Table 2.15 : COM index for rail market liberalization (Kirchner, 2011).

Country	COM index for liberalization
UK	866
The Netherlands	680
Denmark	655
Estonia	629
Germany	615
Sweden	577
Austria	575
Hungary	522
Poland	518
Italy	470
Portugal	434
Belgium	424
Czech Rep.	422
Bulgaria	421
Latvia	411
France	334
Spain	333
Finland	156
Lithuania	120

2.9.3 Efficiency of the market liberalization

In the literature, there is an extensive econometric study on the reforms of European railways and the impacts of the reformations on costs and demand. Detailed studies have been conducted to evaluate the impacts of horizontal and vertical separation. As for the vertical separation, there are some contradicting evidences where some scholars and practitioners believe that these reforms have resulted in cost increment (Growitsch and Wetzel, 2009) while some others advocate cost reductions (Mizutani et al, 2015). In another study by Mizutani and Uranishi (2013), they suggest that vertical separation may lead to cost increase for widely-used railways but cost reduction for less busy ones.

From another perspective, some scholars investigated the liberalization process with a European-wide view (Duranton et al, 2015; Kirchner, 2011) while some others preferred to work on selected case studies (Islam and Eidhammer,2016). In 2002, Kirchner developed his first index related to rail liberalization and performance in Europe which was RailLIB. This method aimed to identify the market opening degree using estimated variables in passenger and freight transportation. He improved the index in 2011 and introduced three levels of rail market liberalization in European countries as is shown in Figure 2.20. Due to this criteria, liberalization-

leading countries such as Sweden, Germany and UK are placed in the most advanced groups where countries such as Spain, Greece and Baltic states remain in delayed group.

Durantan et al (2015) developed a Railway Performance Index (RPI) by exploring the relation between public cost and performance. Figure 2.21 illustrates their approach of efficiency among European railways. In their work, they categorize three dimensions: (i) intensity of use (ii) service quality and (iii) safety issues for both passenger and freight transportation. Fraszczyket et al (2016) analyzed and explained RalLIB and RPI in a more detailed manner.

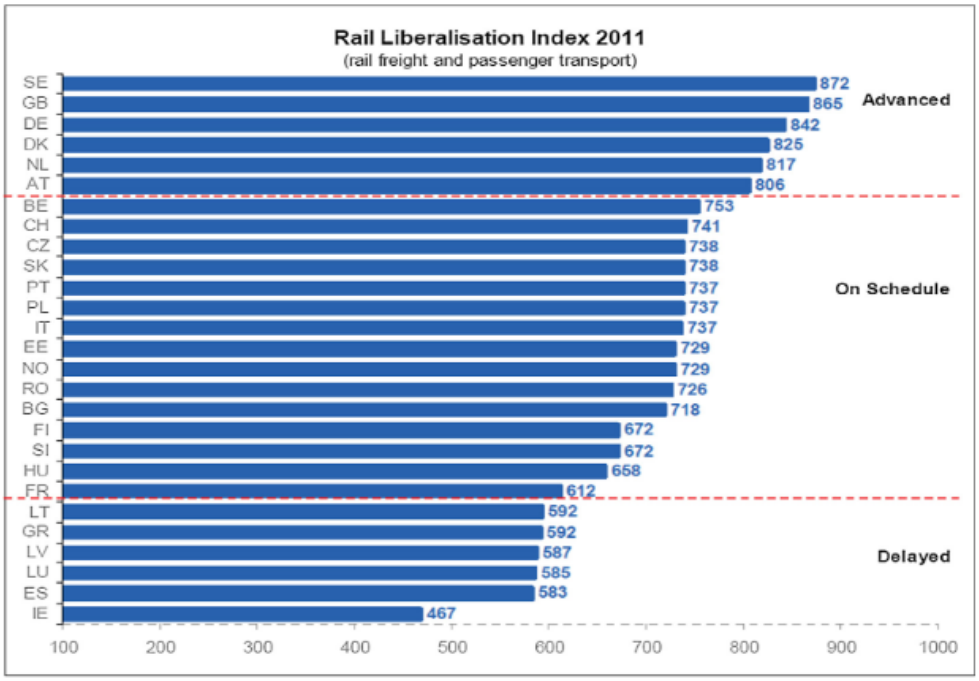

Figure 2.20: Kirchner RailLIB index, 2011.

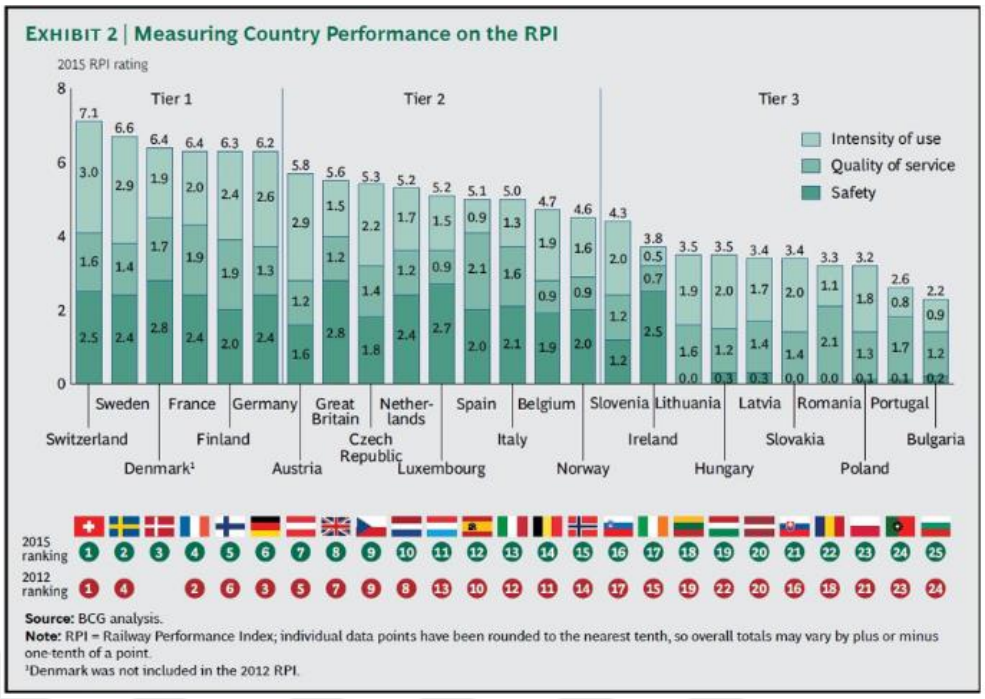

Figure 2.21 : RPI index, 2015 (Fraszczyket, 2016).

A review of different rail reform models was presented by Nash (2008) where he compares UK, Germany and Sweden as the greatest liberalized rail markets and concludes that the most effective mode for passenger transportation is franchising and the most triggering action for market-entry is vertical separation.

Beria et al (2012) found limited levels of market opening and benefits of vertical separation caused by deregulations in four European countries: France, Germany, Spain and Italy. Holvad et al (2015) examined productivity of the market after liberalization in five countries including UK, Denmark, Germany, France and Sweden where he they concluded that Denmark has reached a maximum level of productivity, UK and Germany have also high levels, France has not met the expectations and Sweden has shown the lowest level. However, many studies have shown that there is not yet enough evidence to select the best applicable approach while assessing rail liberalization of national railways (Finger, 2014; Cantos et al, 2012; Beria et al, 2012).

South Eastern European countries that tend to enter EU also follow the rail market liberalization. In a research presented by Boskovic and Bugarinovic (2015), it is mentioned that the liberalization in this region has not been harmonized and this matter results in formation of barriers to implement such projects. Calthrop and Ludewig (2005) evaluated the liberalization of rail market in EU countries by

conducting a survey where they considered user satisfaction, statistical data such as revenue, modal share, freight volume, number of new entrants and number of passengers. Holvad et al 2015 examined a similar approach with the data on labor and capital productivity.

Interoperability of the railways in 11 countries of North-South European region was assessed by Walker et al (2009). They found that political transparency, bureaucracy, public awareness, technological considerations economic conditions and institutional processes shape up the major barriers in realization of a successful liberalization process. However, they believe that the mentioned factors are more problematic in southern countries compared to the Nordic European countries.

Streichfuss (2010) analyzes the process from a different perspective and believes that there may be three essential steps to reach a successful rail market liberalization and boost: (i) market opening competition, (ii) development of modern technologies and rail infrastructure and (iii) application of road charges. To sum up, one may conclude that rail market restructuring may depict controversial effects with regard to the conditions of the countries.

2.10 Track Access Charge Regimes

We will frequently use the term "Track Access Charge" (TAC) in upcoming chapters. Thus, it is beneficial to present a comprehensive framework for TAC regimes, particularly in Europe. Animating the competition in rail market and reaching higher efficiencies require proper charging regimes for the utilization of infrastructure to ensure a fair and nondiscriminatory access of PTSOs to the network. Structure of the charging regime should be in accordance with the market (passenger, freight, HSR, commuter rail). Long-term financial sustainability of the network might be endangered by undercharging PTSOs. The common experience shows that undercharging passenger PTSOs often results in overcharging the freight which leads to losing competitiveness with highway haulage. An appropriate charging regime follows three main objectives:

- Promotion of the financial stability for Infrastructure Providers (IP)
- Provision of effective pricing signals for rail infrastructure users
- Boosting efficiency and competition in the market

TAC should reflect the marginal costs which are directly imposed by the PTSOs to the IP. Externalities such as air and noise pollution, congestion and accidents should be added as external costs to the mentioned direct costs in proportion to the amount that each PTSO generates. This approach forms the Social Marginal Costs (SMC) and it may result in the highest efficiency of the infrastructure if implemented correctly. However, EU allows member states to collect more than SMC by mark-ups on marginal costs. These mark-ups have to encourage efficiency and avoid creation of discrimination among PTSOs. This charging regime is called MC^{+} (Marginal Cost Plus). It can provide the most powerful trade-off between efficiency and budgetary requirements. The last charging regime is FC^{-} (Financial Costs Minus) which tries to fully cover the gap between state contribution and full financial costs and put less pressure on the state.

TAC regimes are generally being established either by use of simple tariffs or two-part tariffs. In the first case, charging level varies directly with the network usage (train-km gross tonne-km). In the second one, the first part is variable with use and another part is fixed in advance with regard to the requirements of the expected capacity (train path-km or train-paths). In less complex rail networks, it is rational to use simple tariffs method due to its easier implementation and less costs. However, in mix-used complex rail networks, two-part tariffs may provide higher efficiencies. Table 2.16 shows TAC regimes in EU states (Railway reforms & charges for the use of infrastructure, 2005). As is clear from the table, MC^{+} is the most common approach particularly in Western Europe countries which is also recommended by Directive 2001/14. They tend to compensate for at least a part of their renewal and maintenance costs, in some cases costs of traffic management and also contribution to investment.

Table 2.16 : Summary of TAC regimes in EU states.

Country	Pricing principle	Fixed charge	Charges per gross t-km	Train-km	Path-km
Austria	MC^+		✔	✔	
Belgium	FC^-				
Czech Rep	MC^+		✔	✔	
Denmark	MC^+			✔	
Estonia	FC^-	✔	✔	✔	
France	MC^+	✔		✔	✔
Germany	FC^-			✔	
Italy	FC^-	✔		✔	✔
Netherlands	SMC			✔	
Poland	FC			✔	✔
Portugal	SMC			✔	
Romania	FC	✔	✔		✔
Sweden	MC^+		✔		
Switzerland	MC^+		✔	✔	
UK	MC^+	Franchises only		✔	

With regard to the costing classification, it is a common point to consider fixed and variable costs. Fixed costs are generally those costs which are not dependent on output. However, time period is a key element of fixed costs. In very long runs, sunk costs of past investment are the only source for fixed costs where most of the costs other than wear and tear, and power are classified in very short-term fixed costs. Table 2.17 presents variable costs and their components with regard to the approach of EU countries.

Table 2.17 : Summary of TAC regimes with variable charges in EU states (Railway reforms & charges for the use of infrastructure (2005).

Country	Maintenance	Renewals	Train planning and operations	Congestion and scarcity	Accidents	Environment
Austria	✔			✔		
Czech Rep	✔		✔			
Denmark	✔			✔		
Estonia	✔	✔	✔			
France	✔	✔	✔	✔		
Germany	✔	✔	✔	✔		
Italy			✔	✔		
Netherlands	✔		✔			
Poland	✔	✔	✔			
Portugal	✔		✔			
Romania	✔		✔			
Sweden	✔				✔	✔
Switzerland	✔	✔	✔	✔		Noise bonus
UK	✔	✔		✔		

Variable charges can be evaluated under the following items:

- Maintenance and renewals
- Operations and train planning
- Power
- Congestion and scarcity
- Side services
- External costs
- Mark-ups

As was previously mentioned, TAC regimes might be implemented in two manners: (i) simple charges and (ii) two-part charges. In the first approach, the charges are based on a direct variation with utilization measures such as passenger-km, train-km, gross tonne-km, net tonne-km, kWh of electric traction used, or revenue percentage. These measures may be weighted by rolling stock type, axle loadings, time of day, speed, route and some others. Externalities and charging costs may be charged effectively by implementation of simple charging methods. In small and simple rail networks such as Norway where capacity of the network is far more than the traffic, simple charges might be the most proper approach.

In the second mode, two-part charges, there are some more factors which are directly related to use including the items given in Table 2.17. This approach covers another component based on the capacity forecast in the form of fixed costs of the system. This fixed part might be considered based on scheduled train-km, scheduled path-km or other similar perspectives. Fixed component of the two-part charging systems can be weighted by the factors including but not limited to particular line, time of day, path quality, speed, etc. Passenger rail services (commuter traffic, in particular) are mostly supposed to be associated with the fixed components of two-part systems since peak time use and higher speeds are more demanded compared to the freight services. Two-part charging systems are potentially more expensive and complicated but more accurate. However, another problematic issue in implementation of this approach is the raise of probable discrimination among PTSOs.

Along with fixed costs, variable costs constitute important components, as well. Thomas (2002) declares that marginal costs of track renewals and maintenance range between 10-30% of average renewal and maintenance costs in European countries. Marginal maintenance and renewal costs also vary with the type of rolling stock which is used by a PTSO, train's maximum speed and track characteristics. Most European countries charge PTSOs per train-km. England charges per vehicle-km. Scandinavian countries such as Sweden, Finland and Norway apply charges per tonne-km. Italy bear the entire costs of maintenance and does not charge PTSOs for this item (Railway reforms & charges for the use of infrastructure, 2005).

Operations and train planning (scheduling) is another component of variable costs. European countries follow diverse views on the marginal costs of operations. Some evaluate them in a totally fixed manner (UK, Finland) or in accordance with the planned path (Italy). Some others interrelate this cost to the distance to be traveled, number of connections, or number of congested nodes (Switzerland). In Slovenia there is an extra charge for those PTSOs who operate trains outside the normal operation hours (Railway reforms & charges for the use of infrastructure, 2005). Moreover, planning costs for a complex network such as Germany where tens of PTSOs are active in passenger and freight transport naturally exceed those for highly state-owned operators of France.

The congestion issue becomes important when operation of one train compulsorily delays other trains. Related authorities try to avoid such conflicts in timetable using

optimization methods. However, high track utilization levels make these overlaps remained the case. Some countries such as France apply a reservation charge without regard whether the reserved path is used or not which is an appropriate approach to hamper reallocation of paths to higher value utilizations (Railway reforms & charges for the use of infrastructure, 2005).

Other costs such as use of power, externalities and side services such as marshalling yards, depots and stations are also matters of great importance and require detailed considerations. The last issue is allocated to mark-ups. Figure 2.22 shows the percent of total costs which are covered by TAC payments of PTSOs in 2004 (Railway reforms & charges for the use of infrastructure, 2005). The figure illustrates that the most Western European countries limitate costs recovers to the maximum level of 30% of entire costs of the infrastructure. In contrast, some Eastern and Central European countries target to collect 100% of total costs through TAC regimes. The blue and light shadings represent Western European countries and Central/Eastern European countries, respectively.

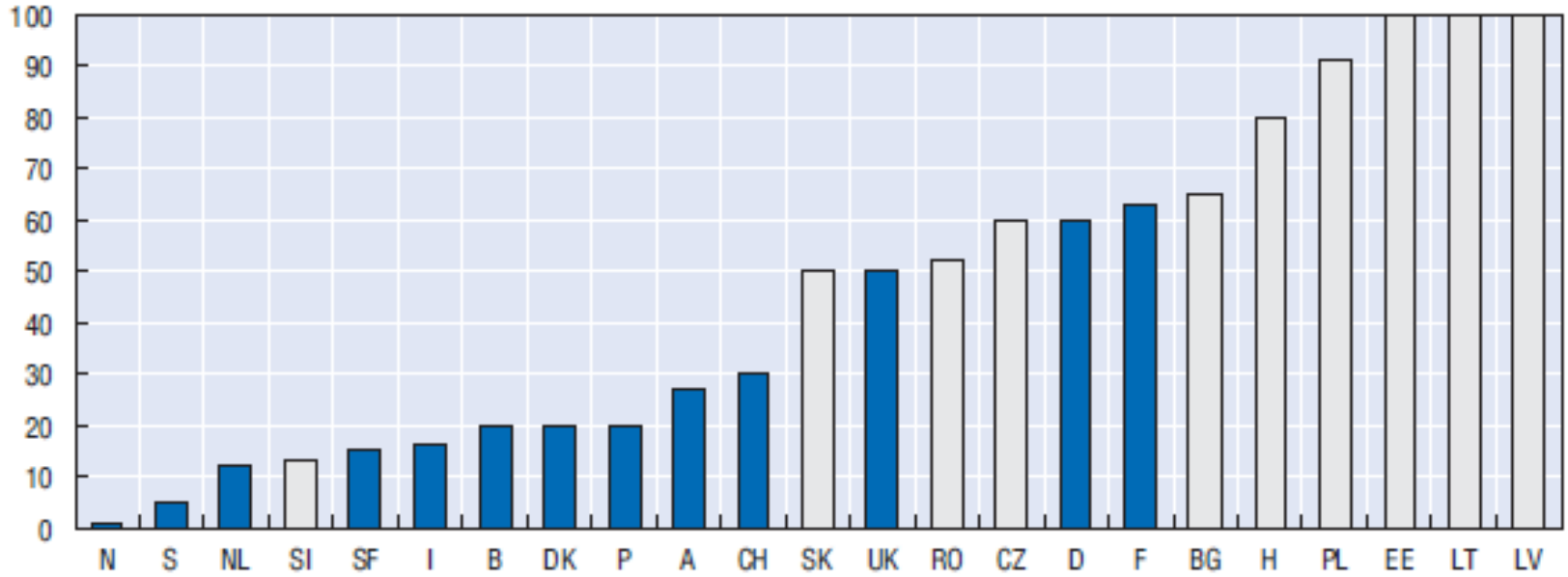

Figure 2.22 : Coverage of infrastructure charges in European countries through TAC systems (Railway reforms & charges for the use of infrastructure, 2005).

3. METHODOLOGY

I presented a detailed and comprehensive study of PPPs in rail and other sectors in the world, the risks, responsibilities and pros and cons of the approach in Chapter 2. At this point, it is essential to link up the thesis and its objective with PPP. I talked about Greenfield and Brownfield PPPs. In the former, private party is also involved in the process of projection and construction of the infrastructure, beside the operation and maintenance. In the latter case, private sector is willing to run services and operation on an existing track provided by the IP. Turkey aims to expand its HSR network in a remarkable portion in close future and this probably will be realized using BOT/PPP approach. In Turkey, there is no HSR project to date completed under BOT approach. Thus, I try to study and evaluate some rail projects realized under BOT in different countries and mainly analyze the conflicts and the ways to obviate them using the basic behavioral modeling of basic games in "Game Theory".

However, the central theme for my thesis is the second approach where I want to propose a multi-objective optimization model to schedule train services in a liberalized rail market. To do this, I developed a NTU cooperative game model which will be presented in following parts. I will also present a sub-division on methodology literature to highlight and make my model clearer.

3.1 Strategic Action Planning for Decision-Makers

PPPs are long-term contracts between public and private parties where service users are another important population involved in the process. Overall success of the system highly depends on the proper integration of these three groups. However, each involved group initially follows its own interests. Each group includes several involved sub-groups, too. Thus, all involved sides have to possess strategic plans compatible with their objectives. They should know the process with all aspects, plan and implement their strategies. A successful strategic action plan must include the following key issues:

Mission: overall purposes of the organization or firm

Guiding principles: guidelines for operating foundations of the organization

Goals: Long-term and broad goals through which the mission accomplishment are defined

Objectives: a realistic and quantifiable measurement of success of a specified goal over an specific time period

Critical factors for success: key issues to be controlled and monitored to achieve objectives

Barriers: potential challenges that might endanger achievement of the objectives

Strategies: a vast set of activities and their probable outcomes in the path of achieving an objective

Actions: concrete steps to be taken by actors to pursue a strategy.

As was previously mentioned, PPP rail projects contain two types of developments: (i) Greenfield and (ii) Brownfield. In the first type, private sector mainly designs, constructs, and operates a new asset on the land provided by the public sector and transfers the facility to the public partner in due time. In the second approach, existing network undergoes a process of liberalization where PTSOs may operate trains on the network. The goals of these parties are antipodal in some cases. PTSOs tend to keep the ticket prices in the highest possible level to maximize their benefits, while the passengers are exactly on the opposition and want to have access to the facilities with low rates and high quality. IP tries to collect high TAC from PTSOs to invest in other infrastructures or renewal of existing tracks, where PTSOs want to pay TAC rates as less as possible. As is clear from these statements, conflict of goals is an inevitable part of such a process and naturally, all sides tend to follow their own objectives. At this point and to model the behavior of involved sides, it was shown that conventional optimization methods whose priority is a system-wide optimization may fail to satisfy the requirements.

Within this context, I have two approaches in evaluation of Greenfield and Brownfield rail projects in this thesis. For the former one, I will evaluate the entire process of long-term PPPs using a Game Theoretic approach with simple 2×2 games and their applicability in actualized rail PPP projects in the world. With this

approach, in this section I try to show the power of "Game Theory" in analyzing the actions and reactions of decision-makers and players of all sides and evaluating the possible outcomes.

In addition, the second case, liberalization of the rail market in Turkey is the main theme of this thesis and I will develop a simulation method for a rail network in Turkey to evaluate all costs and benefits of involved sides in depth and detail using the concept of cooperative games and also schedule train services. Thus, this issue will be separately presented in a separate chapter.

3.1.1 PPP conflict resolution via game theory

Game theory, In contrast to the conventional optimization methods, focuses on the self-interested motivations and behaviors of the players and stakeholders. Indeed, conventional optimization methods' major focus is on a system-wide resolution which leads to a non-realistic approach. Thus, it is clear that some critical insights and policy-making plans might be neglected while using the conventional techniques. Another advantage of game theory in evaluation of the strategic game is its optimization ability in absence of quantitative data by utilization of ordinal game theory. İn such an approach, the only parameter that matters is the rank of the action and its consequences. The trump card of the game theory is its dynamic nature which enables the evaluation of the evolutionary process of long-term PPP projects.

Different interest groups can be modelled as players n a PPP conflict, where the players make choices in a unilateral manner, and the conflict's possible and probable outcomes would be assessed by the combination of the choices by all players. However, this individuality is not necessarily true for all cases and reaching some system-wide Pareto-Optimal resolutions may persuade the players to form coalitions or cooperate. A systematic study of a strategic PPP conflict might provide powerful insights about better dispute resolution by proposing innovative solutions. Many researchers have provided game-theoretic approaches to resolve PPP conflicts (Ouenniche et al, 2016; Glumac et al, 2015; Kennedy, 2013). However, a lack of adequate knowledge about game theory's value on problem predicting and conflict resolution still exists. In this thesis, a number of common games are presented (the Prisoner's Dilemma, Chicken, and the Stag-Hunt game) with their equilibria to cover a vast range of PPP conflicts.

3.1.1.1 Prisoner dilemma game

Prisoner's Dilemma is the most prominent game in explaining the basics of Game Theory. In this game, two suspects in a major crime have been put in separate cells (to prevent the communication in-between) due to being caught red-handed in a minor crime. The police have a suspicion that the suspects are involved in a major crime but lack the significant evidence to convict them of the major crime. The police want to obtain such evidence from the suspects by giving them a tempting offer to cooperate with the police and fink the other and provide information about the major crime. In this manner, Each prisoner has two options, whether to deny the major crime (remain silent) or provide evidence for the police (fink the other suspect). If they both deny the major crime, each of them will spend only two years in prison based on their minor offenses. If only one of them collaborate with the police, he will be used as a witness against the major crime of the other suspect and this will bring him an award of a one-year reduction in his imprisonment period of his minor crime, while the other suspect will sentenced to a 7-year period imprisonment. If they both try to outsmart the other and fink, each will be sentenced to a five-year imprisonment caused by the major crime.

Each player has a set of actions {to fink, to remain silent}. The action profiles ordering from best to worst for the first suspect (player) is as follow: (fink, silent), (silent, silent), (Fink, fink), and (silent, fink). The second suspect's ordering philosophy is the same due to the symmetry of the game. The matrix form of the game with cardinal payoffs (utility) is given in Figure 3.1.a. The values in the matrix represent the number of years each prisoner has to serve in the jail. The left and right values in each cell represent the first and second player's payoff, respectively. The strategies resulting in payoffs for each cell are given on top of the table for the second player and on left for the first player. In this cardinal form, the lower the payoff for a player, the better the outcome is for him (less years to be spent in jail). Another form of the game, ordinal game is represented in Figure 3.1.b. In this case all that matters is the rank of the payoff for the players. In other words, the higher ranks correspond to the more desirable outcomes by the players.

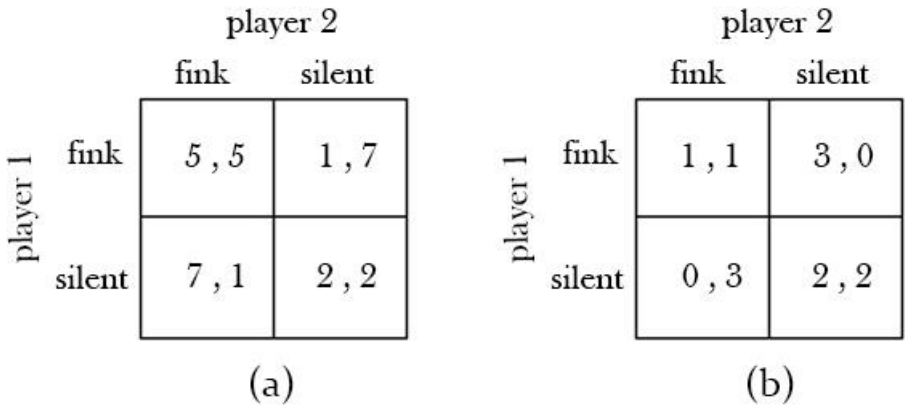

Figure 3.1 : Prisoner's dilemma in (a) cardinal and (b) ordinal payoffs.

As is clear from the matrices, betraying (collaboration with the police) while the opponent is denying the major crime has the best payoff for the given player and worst case for the other suspect. In comparison, it is better to remain silent together rather than finking together. Thus, (fink, fink) is Pareto-inferior to (silent, silent). Pareto-optimal resolution of the game is the case in which both suspects remain silent and deny the major crime. A state is Pareto-optimal in which there exists no other state where one player can individually do better without harming and putting at least one other player in trouble. However, without regard to what the other player selects to do and based on individualistic thoughts, finking is the best strategy for each player. In real world experiences, (fink, fink) is the most likely resolution of the game under the no-communication anti-trust condition of the game which is also a Nash Equilibrium (Nash, 1950).

At state (fink, fink) player 1 is unwilling to change his strategy from finking to staying silent as 1>0. (Silent, silent) would be the most probable resolution of the game while using conventional optimization tools since it has the highest payoff from a system-wide perspective (2+2>1+1). As is explained, the major differentiation between the Pareto-optimality and the Nash stability is that in the former, the matter to be underlined is what is good for the whole system without regard to the interests of the individuals and in the latter, the main point is individual-based interests rather than a system-wide optimization. Based on conventional optimization techniques, a utility maximization or cost minimization objective function might be simplified for the system and the problem is solved as a single decision-maker one, with the assumption of all involved players' loyalty to the

optimal resolution of the system. However, it is clear that this is not necessarily true for the real interest cases.

In case of free communication between the players, they may select a cooperative approach leading to a Pareto-optimal resolution. Generally, in games with the Prisoner's Dilemma entity, the fear of being defected by opponents might restrain involved sides from cooperating.

A real-world PPP conflict with a nature similar to that of Prisoner's Dilemma may occur on a joint project. A similar case is the PPP agreement between a private party and the governments of Spain and France in provision of an intercountry rail project. The commitment of the private party was to connect the two border cities (Perpignan-Figueras) and the Spanish government had to link it up with Barcelona, both of which had to be completed simultaneously. Here, each party can either work hard or goof off. Obviously, the timely integration of the line to the Barcelona was essential for the success of the entire project. The ordinal payoff matrix of this PPP project is illustrated in Figure 3.2.a.

In such games, a good grasp of the issue by involved parties, having accurate and binding contracts and offering other forms of trust might result in better cooperative solutions. The optimal outcome for this game is (work hard, work hard) in which both parties endeavor to comply with the PPP agreement. In this situation, the Spanish government fell behind the commitments by having a serious delay in the Barcelona connection which greatly affected the entire success of the system and the private party faced substantial damages in lack of a binding and prescriptive contract. If the game is changed in such a way that a party not fully complying with the agreement would be subjected to the loss of rights and serious penalties, the payoffs would change in relation to the new regulations and enforcements (Figure 3.2.b). To apply a dominant strategy and state (work hard, work hard) which is both a Pareto-optimal and a game-theoretic resolution of the game, accurate penalties and formal guarantees must be applied. This confirms that there will be no free riding in the entire process for either side. In case of free-riders (goof off), the literature generally evaluates the game as Prisoner's Dilemma (Bardhan, 1993). To avoid this, strict regulations and penalties must come into question. In literature there are many studies on regulations and adjudication processes for PPP projects (Medda, 2007; Rossi and Civitillo, 2013; Lopes and Caetano, 2015; Essig and Batran, 2005).

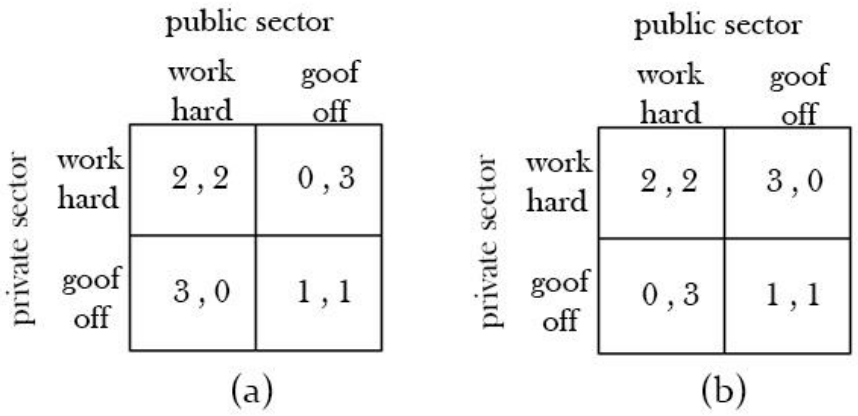

Figure 3.2 : Ordinal payoffs for working on a joint project (a) with and (b) without penalties for defection.

3.1.1.2 Chicken game

"Chicken" game is an important model for a diverse human conflicts range. In this game, two drivers, approaching a narrow bridge, are heading towards each other from opposite directions. The drivers have two choices, whether to swerve (chicken out) or to go straight. The first player to swerve yields the bridge to the other driver and loses the game. In essence, no side entering the race prefers to be chicken. However, if none of them swerve, both drivers might suffer from the worst case, a crash, trying to satisfy their pride. Logically, being called a "Chicken" is far better than dying in a crash. A tie also occurs when both drivers swerve. The payoff for each player can be the utility from winning or losing the game or value of the prize at the end of the game. Figure 3.3 shows the chicken game in an ordinal form. The game has two "Nash Equilibrium" in which one driver wins while the other loses, (swerve, straight) or (straight, swerve). These cases are also Pareto-optimal. The case of a tie, the socially optimal resolution is also a Pareto-optimal state; however, it might not occur with regard to the players' self-interest-based decisions.

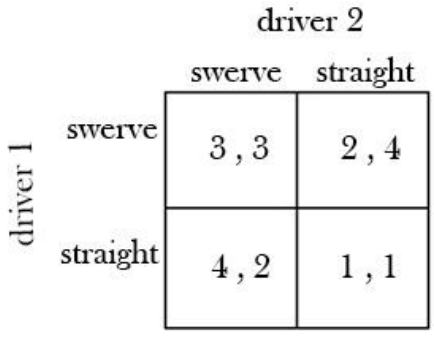

Figure 3.3 : Chicken game with ordinal payoffs.

The strictly dominant strategy of the Chicken game is to play exactly the opposite of what the other side does. One major differentiating aspect of the Chicken game and Prisoner's Dilemma is the case of free riding. In both games, players might prefer to get a free ride rather than find a mutual solution of (silent, silent) or (swerve, swerve). These mutual solutions are not stable and players might refrain from taking them. However, if both players decide to get free rides, the outcome (straight, straight) for the Chicken game leads to the worst case for both drivers (crash); while the state (fink, fink) in Prisoner's Dilemma is not the worst for both players. The structure of the Chicken game leaves no incentive for cooperation since anti-coordination is the dominant strategy and one side wins while the other loses. In a game of Chicken, a good tactic for involved parties is to limit the options of the opposite side by signaling intentions very clearly in the game's early stages. The signal should be aggressive, strong and ostentatious enough to persuade the opponent that defection (driving straight) is not the solution or right choice for them.

The Chicken game can be vastly used in the time slot allocation of rival firms running a popular passenger train route between two cities. After the rail market opening, a newcomer firm "B" might compete with a former government-based monopoly incumbent "A". Suppose that the morning train preference is 60 to 40 percent over the evening schedule and firm "A" is preferred to firm "B" at a ratio of 4 to 1 by costumers due to the firm A's background. The payoffs are shown in Figure 3.4 for this strategy combination.

		firm B: morning	firm B: evening
firm A	morning	48 , 12	60 , 40
	evening	40 , 60	8 , 32

Figure 3.4 : Firms' competition throughout Chicken game.

For firm "B", it is logical to chicken out and avoid direct competition with "A"; thus, the best response for firm "B" with regard to the motions of "A" is to select a time schedule not chosen by firm "A" and this approach is similar to the Chicken game.

The pure strategy Nash Equilibrium for this hypothetical game is: $NE^{ps}_{firmA,firmB} = (morning, evening)$

3.1.1.3 Stag-Hunt game

In this game, two hunters who are out hunting have two options, whether to remain attentive to the pursuit of a stag, or to go for a hare. The stag might be hunted and divided equally only if both hunters pursue it, while each hunter can individually hunt a hare. A stag has the highest payoff for both hunters since the value of half of it outweighs that for a hare itself. However, the worst case for a hunter is when he remains faithful to the cooperative approach (going for stag) while the other player tends to defect (hunting a hare). Figure 3.5 shows the payoff matrix for Stag-Hunt game in an ordinal form.

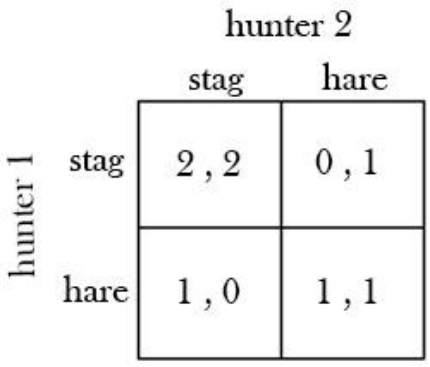

Figure 3.5 : Stag-Hunt game with ordinal payoffs.

Stag-Hunt is similar to the Prisoner's Dilemma where both are games for collaboration. For both, the cooperative resolution is Pareto-optimal and the non-cooperative Pareto-inferior resolution is a Nash Equilibrium. The Stag-Hunt has two Nash equilibriums with no strictly dominant strategy. Unlike Chicken game, the best response for a player in Stag-Hunt is to do exactly what the other player does. At first glance, Stag-Hunt does not look like a dilemma. However, in game-theoretic approaches, it might be regarded as a dilemma where players do not always tend to cooperate to reach the only Pareto-optimal resolution of the game, (Stag, Stag). In practice, due to the lack of trust between the sides, a non-cooperative approach leading to a Pareto- inferior result (Hare, Hare), might be preferred by players. From this perspective, the game can be also labelled as "Trust Dilemma" (Grim et al, 1999). In the Stag-Hunt game, if players trust each other, the risk of failing to cooperate remains very low and the players will cooperate. However, a risk-free

strategy is non-cooperation which results in an outcome with a lower payoff compared to one in which the players cooperate; where the outcome is at least better than the worst case in presence of distrust.

In a Stag-Hunt game, there is no tendency to free ride since the payoff for non-cooperation is not sensitive to what the other player does. Consequently, if a player receives signs of cooperation from the other side, there would be no motivation for non-cooperation. In an analogous manner with Prisoner's Dilemma, repetition of a Stag-Hunt game can help reinforce trust among the involved parties and this might lead to a Pareto-optimal resolution.

Figure 3.6 shows a PPP project with a Stag-Hunt structure. FIFA World Cup 2010 was an ideal motivation for the government of South Africa to deliver a rapid rail link project. The contract was agreed a few years before South Africa qualified to host the tournament and the project delivery date was after the tournament realization. An earlier delivery of the project prior to the commencement of the games would have been a serious facilitator for transport and a spectacular success for the government. Besides, the private party would benefit from the supplementary financial items granted by the government. However, more effort presented by only one side could not suffice to reach the goal.

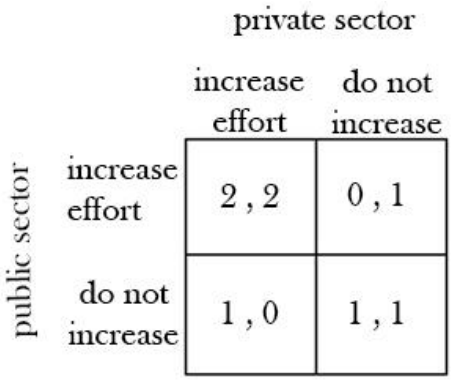

Figure 3.6 : Evaluating a common strategy for early delivery of the service by public and private sectors.

The payoff for the public sector was the remarkable improvement of the transport quality and related revenues during the World Cup period minus the costs of bringing forward the delivery date, to be paid to the private sector. In addition, the private sector's payoff was the extra money received from the government minus the costs of terminating the project in a shorter time span. If both parties work harder and

remain loyal to the new greater goal, their benefits may exceed the costs of extra effort and be well worth it. However, by repetition of the game or as time progresses, signs of lack of commitment to the new undertaking from one side would be an obstacle in reaching a successful fulfilment of the process. The game has two equilibria, the cooperative one (increase effort, increase effort) and the non-cooperative one (do not increase effort, do not increase effort).

3.1.1.4 Game evolution over time

While modelling conflicts, the most important task to be regarded by a wise modeler is about the identification of the game conditions and the probable changes in these conditions in the process of time. Values of players are highly sensitive to the payoff functions and changes in the conditions of the game can seriously affect the payoff functions over time. The structure of the game, its equilibria and the outcomes provided by game theory might be altered in case the game conditions undergo changes. Thus, all players and the modeler should be aware of changing conditions and they should evaluate the game in its course of evolution. Players may reduce their risks of future lower payoffs by having early knowledge of the changing game structure.

Previously, it was mentioned that governments were looking for methods to boost competition in the rail sector. One important measure was to separate the infrastructure provision and operation. In this context, the market had to experience a liberalization process and fair access to the rail infrastructure would be provided to the authorized private operating firms. In this case two or more private operators may gain rights to operate train services on a specific line and the public party acts as an Infrastructure Provider (IP). In such a cooperative framework between a public entity and private partners and subsequent to the iterative rounds of negotiations in-between, the private firms operate train services for a predefined period of time to make a profit and they approve of a payment to the infrastructure provider as the Track Access Charge (TAC) on the basis of the contract. However, in such an environment problems and conflicts often evolve over time. To find useful insights into the conflicts and rational solutions, it is essential to have knowledge of the changing payoffs and the structure of the problem.

To better explain the dynamic nature of the long-term PPP rail projects, a case is considered where two private firms have gained the operation and maintenance rights of a rail track between two cities for a median period of time. The firms provide train services for the passengers and tend to raise their revenues by presenting high quality services. Revenue intakes and the amounts of money to be paid for track maintenance shape up the firms' payoffs. In this manner, the payoff for each firm is equal to its revenue intakes minus the maintenance costs. As is often the case, the system may not entail serious maintenance in the early years of the service. However, defects in the track may gradually arise as time progresses. These defects may seem unimportant at first glance. However, lack of timely and appropriate maintaining measures may result in further serious problems and even a system failure in the future. Within this scope, timely interventions in the track maintenance are required to sustain the service quality.

In this example and with regard to the explanations above, four possible periods are considered during the PPP agreement in which the track is not in need of any immediate maintenance during the initial service years (first period). In the second period, the track maintenance becomes more of an issue but still does not jeopardize the system success. From the third period on, ignoring track maintenance begins to cause serious losses to the firms since service quality and passenger satisfaction are badly affected. In the final period, the risk of system failure is imminent so that it is even rational for a firm to solely undertake the maintenance and pay for the maintenance costs since poor quality of services and related revenue losses outweigh the entire maintenance costs. However, it is not true to claim that all similar long-term PPP rail projects will necessarily follow all four periods and this example aims at presenting game theory's power in provision of strategic analysis for all probable cases from the earliest days of the agreement until the end of the project's lifecycle.

Although the aforementioned PPP agreement does not necessarily have four periods in a game theoretic sense and the example is not a transparent case of any special 2×2 game, Game Theory can provide deep insight for all probable periods during the agreement. Thus, the firms may take required measures from the very beginning to the end of the PPP rail agreement. One powerful method in a game-theoretic evaluation of such cases might be the utilization of backward induction. Using this method, one may analyze the process from the end to the beginning in order to

determine the sequence of optimal actions. Thus, at first step the process considers the last time a decision might be made and selects which strategy to follow in any situation at that time. Subsequently, one can determine what to do at the next-to-last stage of the decision. This sequence continues backwards until reaching the best action for every possible situation at any moment throughout the process. In other words, one may determine the Nash equilibrium of the game's sub-games. However, in numerous cases it has been observed that the results inferred from backward induction may fail to predict actual human play. Irrational players who are in search of higher rates of payoffs seldom exhibit rational behavior which is presented by backward induction and they may actually obtain higher payoffs based on their own actions compared to the predictions of backward induction.

In this example each firm has two options while approaching the maintenance costs: {Pay, Don't Pay}, to be denoted by {P, DP}. Figure 3.7 shows how maintenance costs (and revenue losses) change over time and in the different periods for each firm with regard to the four outcomes of the game [(P, P), (P, DP), (DP, P), (DP, DP)]. Within each period presented in Figure 3.7, the four curves change continuously and the interpretation of the curves must be deduced purely based on a qualitative perspective. Afterwards, the firms' payoffs would be calculated as discussed above which is given in Table 3.1.

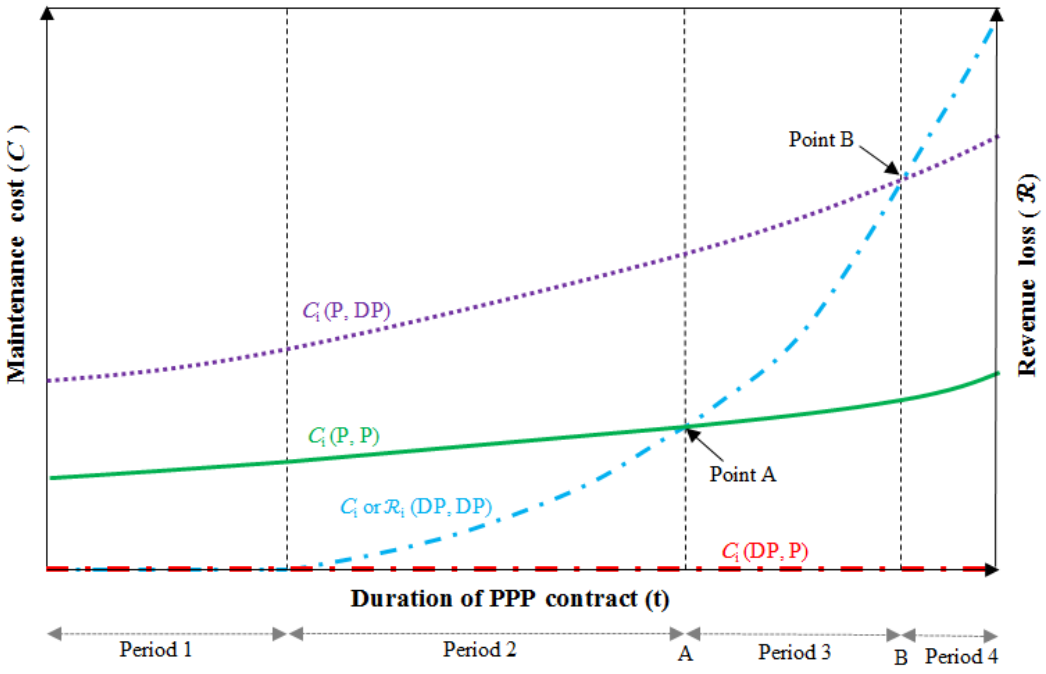

Figure 3.7 : Changes in maintenance costs and revenue during different periods of the PPP rail contract.

Table 3.1 : Maintenance costs in rail system's maintenance conflict and possible outcomes for payoffs.

Outcome (S_i, S_j) S_i, $S_j \in S = \{P, DP\}$	Maintenance costs $C_i(t)$, $C_j(t)$	Payoff $P_i(t)$, $P_j(t)$ $P = R^* - C - \mathcal{R}^{**}$
(P,P)	$C_i(t)$ = Half of the total maintenance cost $C_j(t)$ = Half of the total maintenance cost	$P_i(t) = R_i(t) - C_i(t)$ $P_j(t) = R_j(t) - C_j(t)$
(DP,P)	$C_i(t)$ = Half of the total maintenance cost $C_j(t)$ = Half of the total maintenance cost	$P_i(t) = R_i(t) - C_i(t)$ $P_j(t) = R_j(t) - C_j(t)$
(P,DP)	$C_i(t) = 0$ $C_j(t)$ = Total maintenance cost	$P_i(t) = R_i(t)$ $P_j(t) = R_j(t) - C_j(t)$
(DP,DP)	$C_i(t)$ = Total maintenance cost $C_j(t) = 0$	$P_i(t) = R_i(t) - C_i(t)$ $P_j(t) = R_j(t)$

* R: Revenue intake; **$\mathcal{R}$: Revenue loss caused by poor services

An ordinal presentation of the firms' payoffs during various periods of the PPP agreement is given in Figure 3.8. The payoffs for both firms are the same due to the symmetry of the example. The first strategy mentioned in parentheses is related to player i and the second one belongs to player $j \neq i$ where $i,j \in N=\{$firm 1,firm 2$\}$. Indeed, the lengths of the periods on the X axis are representative and may differ for different cases and projects. For instance, in a track there may be no need for a serious maintenance during the first three years where for another one this period may be far shorter or longer. The length of the first two periods along the horizontal axis is longer compared to the last periods since during initial years of the service, the infrastructure would not obtain severe damages and they would be eliminated by minimal on-time interventions. However, in absence of the required periodic repair and maintenance, permanent damages may occur later on and afterwards, the efficiency of the infrastructure may swiftly decrease and in a slightly shorter timeframe it may even fail to give proper services. The curve (DP, P) in Figure 3.7 implies that the payoff for firm "i" is at its highest level since the firm does not pay for the maintenance and the rival firm pays for it from the beginning so that there is no risk of system failure and the payoff for firm "i" equals its revenue. In a case of (P, P) both firms tend to pay for the maintenance costs and they share these costs during all periods. In this case the slope of the curve slightly increases in a steady manner and the firms' payoffs are equal to their revenues minus half of the maintenance costs. The case with lowest payoff for firm "i" is (P, DP) where it undertakes the total costs of maintenance and the rival acts as a free rider. The payoff for the firm "i" is its revenue intake minus the total amount to be paid as maintenance costs. The slope of the curve is steeper towards the final periods since

the defects in the track become more serious and they require efficient and more costly interventions. In case (DP, DP) and during very first years of the services, there would be no risk of serious reduction in payoff for both firms. However, the curve follows the steepest ascending manner in the process of time and lack of required maintaining measures may lead to remarkable losses in revenues and parallel payoffs. At point "A", where curves (DP, DP) and (P, P) collide, the economic loss due to a low quality of services is equal to half of the required maintenance costs. This implies that from point "A" on, it is logical for each firm to pay its own share of maintenance costs. Where (DP, DP) and (P, DP) intersect, point "B", the economic loss for firm "i" is equal to the entire cost of maintenance and firm "i" has to pay for the maintenance costs even if the rival firm refuses to pay. Consequently, at least one side has to chicken out and pay for the maintenance costs after point B to avoid considerable revenue losses of a low-quality track. Otherwise, shortly afterwards, the service is doomed to failure.

Table 3.1 showed the calculation of the costs and resulted payoffs over time and different periods in a cardinal form. During the first period, the firms can pay for the required minimal maintenance costs. However, the risk of failure at this period is negligible since during the very first years of the operations there may be no serious defect in the system. Therefore, the payoff for the firm who pays for the minimal costs of the maintenance equal to its revenue intakes minus the mentioned costs (in case the maintenance costs are paid by both firms, the costs are divided into two equal portions). Since there is no risk of failure during this period, the risk-taking firm may decide not to pay for the maintenance costs. However, over the course of time and if no maintenance is performed, the failure risk and maintenance costs start to undergo an ascending trend. In the second period, the failure risk incessantly grows but the related economic loss of each firm is still less than half of the required maintenance costs. If only one firm accepts to pay the maintenance costs at this period, its payoff remarkably falls since the entire cost of maintenance is undertaken by that one firm and the other firm gets a free ride. In the 3rd period and in case no firm pays for the maintenance costs, the risk of economic loss begins to transcend the half of the value for maintenance costs. If both firms insist on not paying for the maintenance costs, during the final period, the economic loss of the firms become more than the total costs of maintenance. Thus, the points "A" and "B" corresponds

to the points where economic loss of each firm is half and total of maintenance costs, respectively.

The structural evolution of the rail system's maintenance game and ordinal payoffs for the firms over time are shown in Figure 3.8 and Table 3.2. Clearly, the Nash equilibria and Pareto-optimal outcomes change as the nature of the problem changes.

During the first and second periods (Figure 3.8.a and 3.8.b, respectively) and at point A (Figure 3.8.c), the strictly dominant strategy of the game is DP and (DP, DP) is the only dominant strategy (Nash) equilibrium and one of the Pareto-optimal outcomes. The problem has some other Pareto-optimal outcomes in the second period and at point A, but they are not Nash equilibria and the Game Theory suggests that firms are reluctant to share the costs and pay maintenance costs during this period and point.

At point A, (P, P) begins to be a socially optimal (Pareto-optimal) outcome of the game. However, it is not a possible solution for the conflict based upon Nash solution. In the 3rd period (Figure 3.8.d) the nature of the game is analogous to that of the Prisoner's Dilemma game. DP is the strictly dominant strategy yet and (DP, DP) is the Nash equilibrium and the dominant strategy. It is also Pareto-inferior to (P, P), a case in which both firms pay the maintenance costs. However, firms may decide not to share the maintenance costs and pay for it in this period due to the stability definition of the Nash solution and they may prefer to be a free rider. At point B (Figure 3.8.e), DP is still a dominant strategy but not the only one (strictly dominant) anymore (3>2 and 1=1). At this point, three Nash equilibria of the game are: (DP, P), (P, DP), and (DP, DP). The cases (DP, P) and (P, DP) are also Pareto-optimal outcomes of the rail system maintenance game. Game Theory suggests that from point B on, the game may turn out to be a game of Chicken. In this period, the risk-averse firm may prefer to chicken out and take the responsibility solely on himself to pay the maintenance costs in order to avoid serious revenue losses from the rail system's failure.

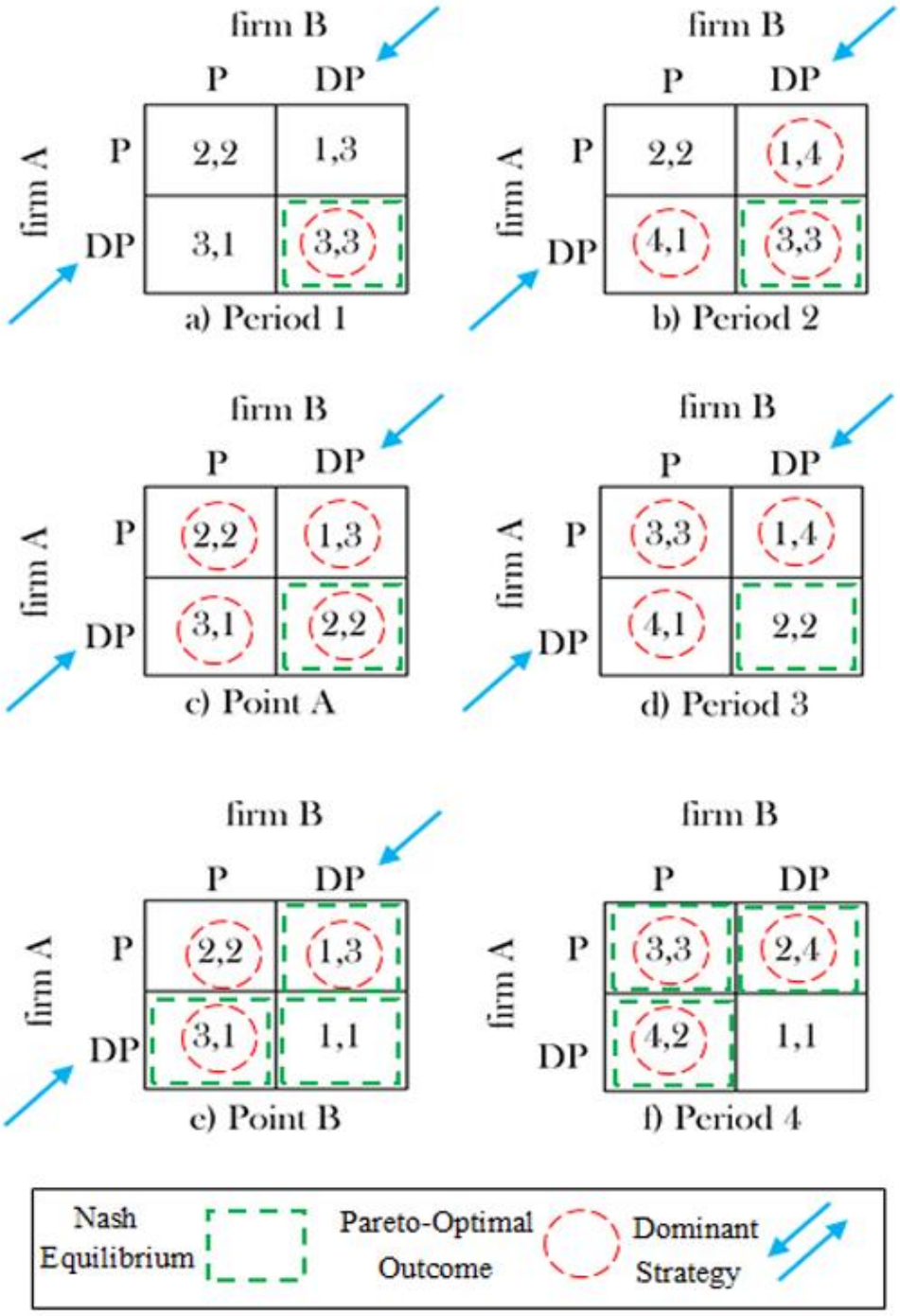

Figure 3.8: Rail system's maintenance game over time.

It is clear that each state significantly affects and changes the conflict problem. Considering the evolutionary entity of the problem, game theory provides powerful tools to explain the changes in players' behaviors. Within this context, while modelling the problem it is a matter of crucial importance to recognize the correct stage and period of the problem. The results and evaluations might be misinterpreted

or incorrect in case the evolution of the game is not noticed. Table 3.2 shows the strategies of firms and related payoffs in different periods of the process.

Table 3.2 : Rail system's maintenance game and its characteristics at different periods.

	Period 1	Period 2	Point A	Period 3	Point B	Period 4
Strictly dominant strategy	DP	DP	DP	DP	-	-
dominant strategy	DP	DP	DP	DP	DP	-
Nash Equilibria	(DP,DP)	(DP,DP)	(DP,DP)	(DP,DP)	(P,DP), (DP,P), (DP,DP)	(P,DP), (DP,P)
Dominant strategy equilibrium	(DP,DP)	(DP,DP)	(DP,DP)	(DP,DP)	(DP,DP)	-
Pareto-optimal outcomes	(DP,DP)	(DP,P), (P,DP), (DP,DP)	(P,P), (DP,DP), (P,DP), (DP,P)	(P,DP), (DP,P), (P,P)	(P,P), (P,DP), (DP,P)	(P,P), (P,DP), (DP,P)

Undoubtedly, sharing the maintenance costs by two firms from the very beginning of the operation would be the optimal solution for rail track system. However, the lack of a clear understanding of the problem, the evolutionary trend of the game over time and the risk tolerance of a rival firm may convince the firms of refraining from selecting this optimal solution. In many cases, the players' perspective may not be broad enough and they may make their decisions based on the current conditions without regard to future changes. For instance, if a player has a perfect foresight about the changing nature of the game and is sure that the opponent is more aggressive with a higher rate of risk tolerance, he would chicken out early in the game to pay the entire amount of the maintenance costs to avoid higher costs in the future and risk of revenue loss. In contrast, if the player is sure of himself in risk tolerance, he would tend to prolong the game to reach the 4^{th} period of Figure 3.7 to force the rival to pay the maintenance costs and chicken out. Another reasonable and wise decision made by both firms' decision-makers may be the case in which both firms tend not to pay for the maintenance costs up to point "A" in the project (since customer loss is not yet a concern) and they make a compromise to share the costs of maintenance from such a point on to avoid further serious customer and revenue losses. Game Theory provides such an environment and insight for decision-makers of the firms to analyze the rival and its behavior, evaluate the possible actions and

reactions, advantages and disadvantages of each strategy and foresee the probable outcomes.

3.1.1.5 Cooperative games

In a Cooperative or Coalitional Game (CG), the focus of the model is on interacting decision-makers with regard to the behaviors of groups of players rather than their individual actions. This differentiates CG from strategic and extensive games which are other two major fields of Game Theory. Each group of the players are called "a coalition" where "grand coalition" arises in case of the coalition of all the players. Outcomes of coalitional games include partition of the set of players into groups alongside the actions for each group in the partition. In general, in a CG, players care about the actions selected by each group in the partition and their outcomes. Thus, each player's preference in a CG rank the actions of all possible groups of players that include him.

Components of a CG is as follows:

- Players' set
- Set of actions for each coalition (group in the partition)
- Preferences over the set of all actions of all coalitions of which the player is a member

It should be noted that CG does not necessarily relate the actions of the members of the coalition to the actions of that coalition. In other words, the actions of a coalition are not derived from the actions of individual players in that coalition. Players tend to participate in coalitions when the benefits of a cooperative approach outweigh that for acting individually. In this case, there are remarkable incentives for players to coalesce. In many cases, there would be no disadvantage for a player to take part in the grand coalition. Such games in which the outcomes of the formation of the grand coalition is at least as desirable for every player as the results by any other partition are called "cohesive".

"Core" is another important term in CGs which is the expected action to be selected by grand coalition. In this manner, grand coalition looks for the stable actions where no other coalition can break them away. Thus, the core is defined as the set of all

stable actions to be selected by grand coalition. If any coalition (other than grand) offers an action which is preferred by all its members (players) to some actions of the grand coalition, it can be claimed that the specific coalition improves upon the grand coalition. Therefore, the core of a CG is grand coalition's all action upon which no other coalition can improve. The core of a CG always exists; however, it may be an empty set in which no action is immune to deviations.

In some CG examples, each coalition "S" and their action sets are the set of "S-allocations of the output that "S" can reach. Preferences of each members in "S" then be obtained as the amount of outputs he receives. Thus, it can be noted that the total output of a coalition contains the contributions of all its members while the payoffs will be distributed among the members in a pre-agreed way. CGs where the distribution of payoffs may be represented in this manner are called games with "transferable utility". An obvious example of Transferable Utility Coalition Game (TUCG) in Turkey is formation of political coalitions such as the "People's Alliance" (Turkish: Cumhur Ittifaki) and "Nation Alliance" (Turkish: Millet Ittifaki) to gain parliamentary majority or mayoral elections during 2016-2019 period.

However, a wide range of CGs includes payoffs which are not transferable. In this study, it is targeted to simulate and evaluate a Brownfield type of PPP rail project with market liberalization in Turkey where the payoffs are non-transferable. Thus, the concept of Non-Transferable Utility Coalition Game (NTUCG) and their solutions will be presented in detail and more in depth in the next chapter.

3.2 Literature on Train Scheduling and Optimization Methods

In a liberalized rail sector, three "agents" who have conflicting objectives are involved. Passengers want to have easy access to the rail services compatible with their travel schedules and their budget. Private Train Service Operators (PTSO) aim to their utmost to maximize profit. Thus, they have to analyze their costs including but not limited to the rolling stock leases, maintenance, energy costs for traction, staff, Track Access Charge (TAC), fixed and variable charges related to the network and more incidental expenditures, such as advertising, and rental costs. Each of these costs has a complicated structure in essence. Vehicles' age and the equipment fitted to them seriously affect the lease costs. High-speed rail operations require increased energy consumption and greater maintenance levels. Services with on-board facilities

for passengers increase staff costs. The type of rolling stock and the annual mileages designate the TAC level to be paid to the Infrastructure Provider (IP). Train sets' energy source is also an important factor to be considered where electric rolling stock is more efficient than diesel powered locomotives. In addition to all these considerations, the private operators must pursue effective pricing strategies for ticketing as one of their most important income sources.

When it comes to the public agencies, they chase two principal goals. Primarily, they are in charge of providing inclusive train services to the community that is appealing for the users of various socio-economic groups. Furthermore, they seek effective ways to compensate for a remarkable portion of track expenditures via applying TAC regimes to the private train operators.

Therefore, the research question is how to evaluate resource allocation and timetables, service quality, users' satisfaction levels and the utilization of the infrastructure capacity with regard to the conditions of new open market and complex negotiation procedures? A conceivable approach to address this question is computer simulation and various modelling and simulation methods have been tried. Some researchers have applied Multi-Agent System (MAS) tools for an open railway market (Ho et al, 2012; Tsang and Ho, 2008, 2006) whilst others have attempted fuzzy logic applications (Ho et al, 2009; Luo et al, 2003). Machine learning is another area of artificial intelligence that paves the way for analysts to process the negotiation (Wong and Ho, 2010). Game theory has also been used in such negotiation processes (Binmore and Vulkan, 1999; Rubinstein, 1982).

Mathematical programming and auction theory, such as the Binary Conflict Ascending Price (BICAP) method (Brewer and Plott (1996) is another promising research area. Private firms bid to secure access to the rail infrastructure: they may increase their bids to compete with rivals for available slots. Simultaneous ascending auctions are assigned for each train and the submission of bids takes place in real time. This process involves three elements including: a feasible set for outcome allocations; a communicational environment through which private firms interact with the infrastructure provider and each other; and a rule for outcome settings that determines the ultimate outcome. The process of capacity allocation tends to maximize the bids' total value from trains with regard to the feasibility constraints. Each firm may resubmit new bids in an increasing order for trains and the computer

system evaluates whether the newer bid is higher than an existing one for a given train - or not. The system collects the set of bids with the maximized sum of feasible allocations and without any conflict of timing. The mechanism keeps the highest bids as information only and the process ends up at a point in which no more increase in the value occurs.

Nilsson (2002) handled this issue from a different perspective by evaluating two interrelated challenges to solve incentive problems: the mathematical aspects of problem optimization; and the revelation of the private firms' track access values. In the model, PTSOs register their preference on the departure and arrival of desired trains and offer alternatives to the preferred path. Each PTSO submits a bid set for each of their alternatives and identifies the firm's willingness-to-pay for the preferred set and alternative paths. Subsequently, the IP generates the highest possible bids' aggregate values to reach the maximum allocation case. A calculative procedure evaluates the set of prices with regard to the submitted bids. Then, the IP sends back the acquired information to the PTSOs for further consideration. Termination of the process occurs when there is a lack of any conflict between the operators' preferred choices. If conflicts exist between some PTSOs for a path, they have to reconsider their initial specifications. This is an iterative process that continues until no side wants to reconsider its specifications. This approach can provide information about timetabling problems and capacity scarcity and can enlighten decision-makers about the efficiency of track supply.

A graph-based model was introduced by Caprara et al (2002). A single line was considered with stations represented by 2880 nodes: half of them indicating arrival times; and the remaining half related to the departure time (to the closest minute). There are two types of arcs: those connecting one station's node of arrival to its departure node that represents dwell time at the station; and those connecting one station's departure node to next station's arrival node which represents train's inter-station runtime. Thus, an origin-destination path of a train encompasses a sequence of arcs beginning from departure point and ending up with the arrival point. The aim of the model is to determine the maximized total utility of trains by adjusting the departure times and the run-times of trains. A proposed extension of the model is to include multiple tracks in the stations (Caprara et al, 2006).

Lalive and Schmutzler (2008) analyzed the impact of competition on cost reduction and scheduling improvements by measuring the frequencies of trains based on the ratio of train-kilometers per year to the length of the line in the Baden-Wurttemberg State of Germany. They compared the evolution of services on open access lines where competition is allowed with those exposed to direct negotiations with the incumbent. They showed that growth of the service frequency is more observable for competitively procured lines. Furthermore, they suggested that the private operators' behavior plays a crucial role in the overall success of the liberalized market.

Wong and Ho (2010) make use of Reinforcement Learning (RL) approaches to model the behavior of agents during negotiations. The negotiation behavior and reinforcement learning are integrated by mapping stakeholders' behavior to the RL framework. In this system, stakeholders are the learners who are able to learn and to select realistic action sets with regard to their objectives. Both IP and PTSOs may learn to switch to different pricing strategies to guarantee the highest possible overall revenue.

Fragnelli and Sanguineti (2014) introduced an approach to optimize railway timetables using cooperative game theoretic concepts. To attain a Pareto efficient point and to solve the bargaining problem, they applied the Nash solution, the Kalai-Smorodinsky solution and the Egalitarian solution. The model identified a set of PTSOs operating trains on the same line. At the first step, the model provides a communication between each PTSO and the IP about their ideal departure time, associated arrival time, corresponding utility function and feasible time span. The authors also analyzed the cooperative and non-cooperative approaches of the trains using transferable and non-transferable utility approaches, respectively. Their research improves train scheduling when the PTSOs decide to share more data in a cooperative manner. Limitations of this technique based on the PTSOs' resistance to reveal information are presented.

To summarize the problem, from the outset in complex systems, and from an individualistic perspective, all passengers, Private Train Service Operating (PTSO) firms and public agents are decision-makers who are pursuing their own goals. However, despite some radical contrasts in interests, they are forced to collaborate willy-nilly. Conventional optimization methods in analyzing such systems suffer inadequacies because they convert the complicated multi-objective and multi-

decision-maker system into a single decision-maker problem in which a single composite goal is pursued by all players (Madani, 2010): these approaches are unable to reflect the realities of the real world. At this juncture, game theory may provide a suitable tool to fill the gap by analyzing individualistic approaches by those involved. Under the rules of game theory strategic actions of decision makers, emerging responses from other sides and the overall results may be evaluated in a more realistic manner.

As is clear from above-mentioned points, provision of public infrastructure, such as a railway network under a PPP procurement arrangement incorporates a number of interest groups with different anticipations. However, it is not straightforward to make trade-off amongst these groups because their actions and reactions are completely interrelated and every single element of the system naturally follows its own priorities in an individualistic manner. At this point, formation of a fastidious negotiation process between the IP and private firms to allocate track capacity and formulate service timetables are matters of paramount importance. Above-mentioned arguments imply that the nature of "the game" encompasses some sort of cooperation and "the game" is not zero-sum in which one player's loss or gain of utility is completely balanced by other participants' gains or losses. In fact, aggregate losses and gains of interacting agents can be more or less than zero in a non-zero-sum game. Whilst a zero-sum-game is strictly competitive, a non-zero-sum game may be either competitive or not (Peterson, 2017). In a general sense, partial cooperation is the inevitable result of such an open market. In cooperative games, cooperation may pave the way for players to obtain higher rates of payoff by forming coalitions where acting in isolation cannot serve that purpose (Greco et al, 2010).

In this thesis, I develop a simulation model for market liberalization in a rail line (to be fully presented in the next chapter) in Turkey using GoLang programming language and evaluate the perspectives of the IP, PTSOs and passengers (service users). Figure 3.9 illustrates the general framework of the model. I will also provide additional and detailed information about the procedure in following sections of the chapter.

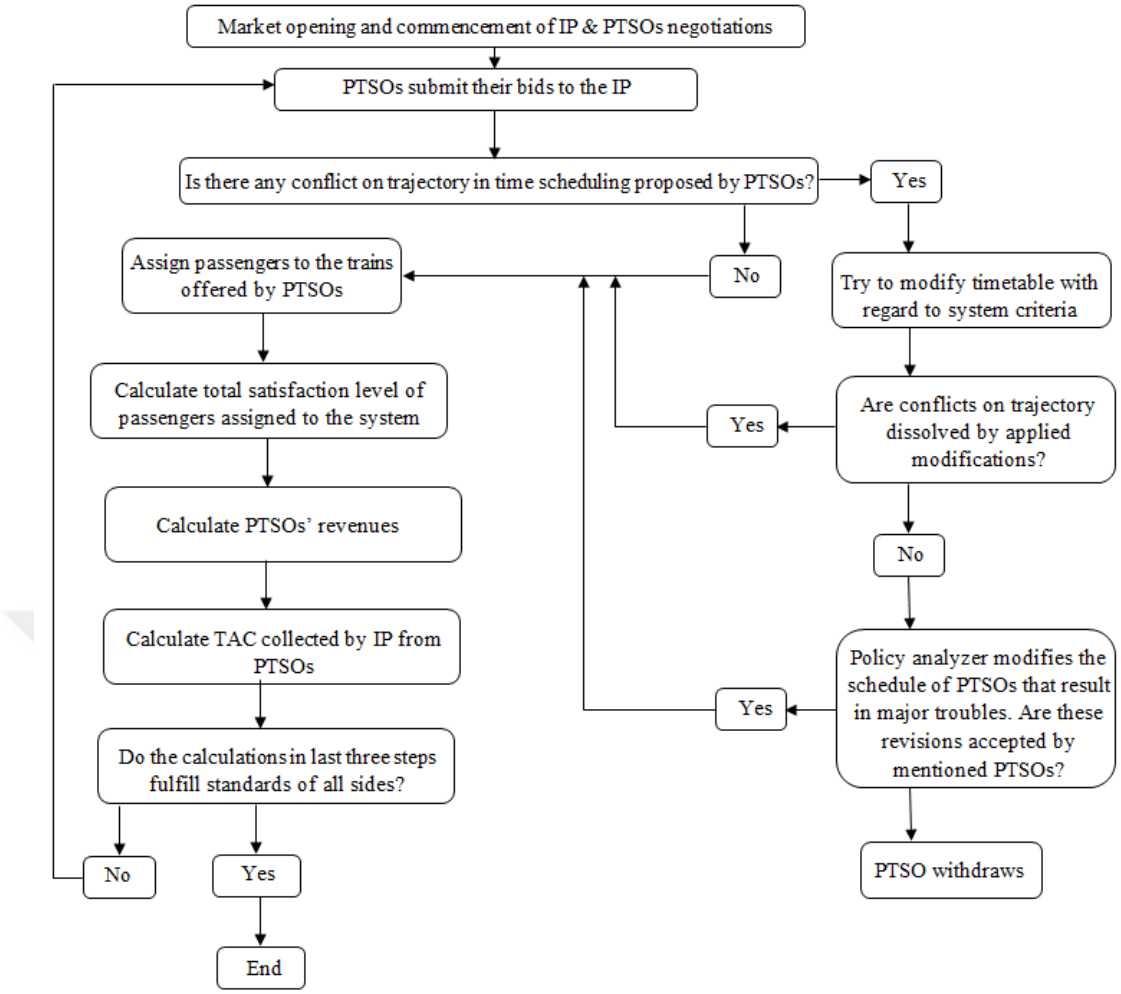

Figure 3.9: Algorithm of the simulation for market liberalization.

3.3 Market Opening and Negotiation Process

In traditional monopolistic rail markets all provisions of infrastructure and train services were undertaken by a single company. However, in liberalized rail markets with firms' open access to the infrastructure, new reforms have posed nascent challenges to railway management. In a liberalized market environment, the stakeholders are self-interested and independent units with diversified business goals (Pietrantonio and Pelkmans, 2004). The contrasts in stakeholders' goals make the market prone to conflicts. For instance, despite high public demand for a certain train service and IP's considerable efforts to maximize track utilization for the public interest, a PTSO may pull out from it due to its low rate of profit. Therefore, efficient resource allocation and track utilization require repetitive negotiations to fulfill anticipations of different parties.

The negotiation problem can be formulated as follows. The components of track access rights, R, are given below:

$$R =< TAC, \omega, \phi, \psi >$$

Where TAC is an agreed track access charge to be paid to the IP by a PTSO; ω is the type of rolling stock to be operated on tracks; ϕ is flex level (Gibson et al, 2002) that denotes IP's revision rights on time scheduling when capacity becomes scarce; and ψ is time schedule that specifies train service details. Train schedule ψ also includes the components as follows:

$$\psi =< S, \xi, T_D, T_R >$$

Where S is set of stations and sequences of them through which trains go; ξ is the service time the train commences; T_D is dwell time at stations; and T_R is inter-station runtimes.

The number of parties involved in the negotiation process is an approach widely-used in the classification of negotiations (Luo et al, 2003). With this approach, bilateral and multilateral negotiations show up where single-PTSO-IP and n-PTSO-IP negotiations come into question, respectively.

In my model, IP initializes the negotiation by requesting the PTSOs to submit their bids based on their train scheduling preferences and conditions. Subsequent to the collection of all bids, IP generally applies two types of timetable generation, namely "sequential timetable generation" and "combinatorial timetable generation". In the former case, IP negotiates with the PTSOs one-by-one in some specific order such as first-come first-served (Tsang, 2007) or intelligent ranking (Ho et al, 2009). In the latter case, the IP takes all constraints imposed by the PTSOs into consideration and it derives a feasible timetable for train services. Compared to sequential timetable generation, higher computation is demanded while using combinatorial timetable generation because of its larger scale in problem optimization. In this study, I take the advantages of combinatorial timetable generation with a comprehensive regard to the thoughts of all parties and players.

Immediately after the identification of the PTSOs' proposed services to the system, the simulator checks whether there is a conflict on train trajectory or not. In case of any conflict, the simulator initially follows some simple rules to fix it. The simulator is permitted to play with the PTSOs' commencement time, ξ, and dwell time at

stations, T_D, at a maximum level of 5 minutes since it is supposed that higher rates may lead to the passenger dissatisfaction of a given train service and further revenue losses. If possible, it is also allowed to increase, or reduce, some PTSOs' trains' mean speeds of up to 10% fluctuations from their preferred speeds to make the conflict happen at stations not on the path since the trains can bypass each other at stations. If these modifications remain inadequate in troubleshooting, the IP requests the concerned PTSOs to revise their timetable planning or the policy analyzers offer alternative solutions to related PTSOs. Figure 3.10, Figure 3.11 and Figure 3.12 show the frequency of passengers during week days and time of the day, and running of some input/output data in GoLang programming language.

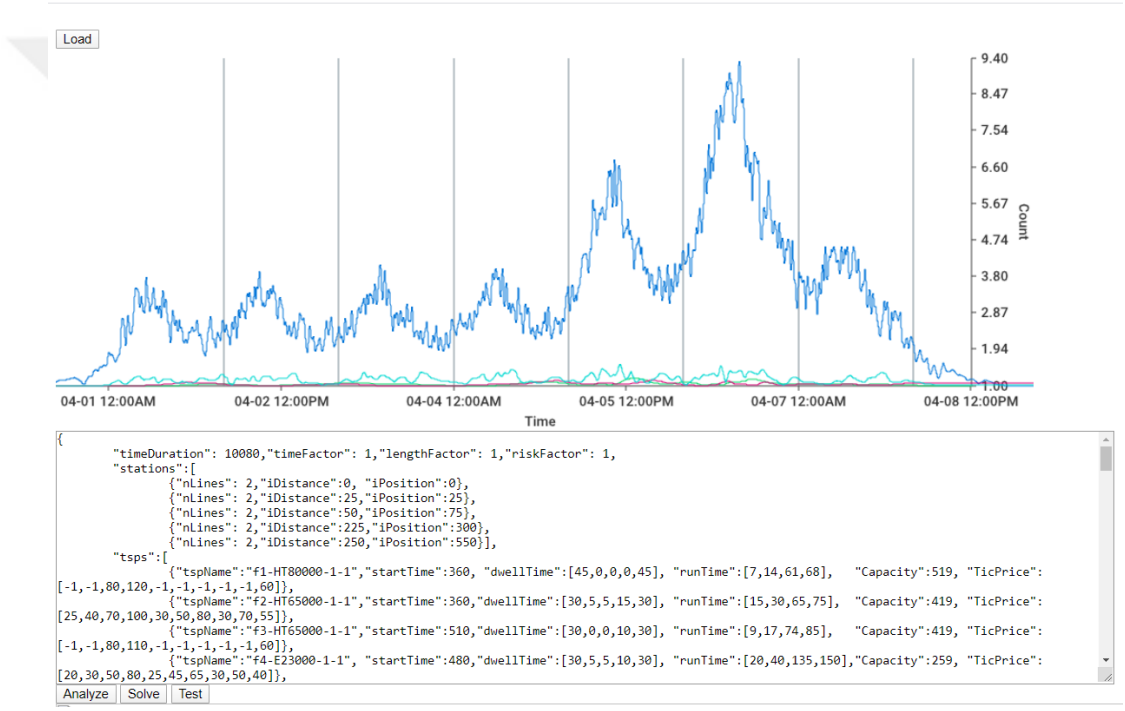

Figure 3.10 : Passenger distribution in GoLang based on days and time spans.

3.4 Analytic Evaluation of the Liberalization Process

In the first chapter, it was mentioned that a quantitative analysis of the rail market liberalization in Turkey will be presented on the basis of the Non-Transferable Utility Coalition Game (NTUCG). It should be restated that the nature of this open market game is cooperative since it is impossible to reach a comprehensive and successful settlement by completely ignoring some players' interests. This guides us towards the coalitional games and formation of grand coalition.

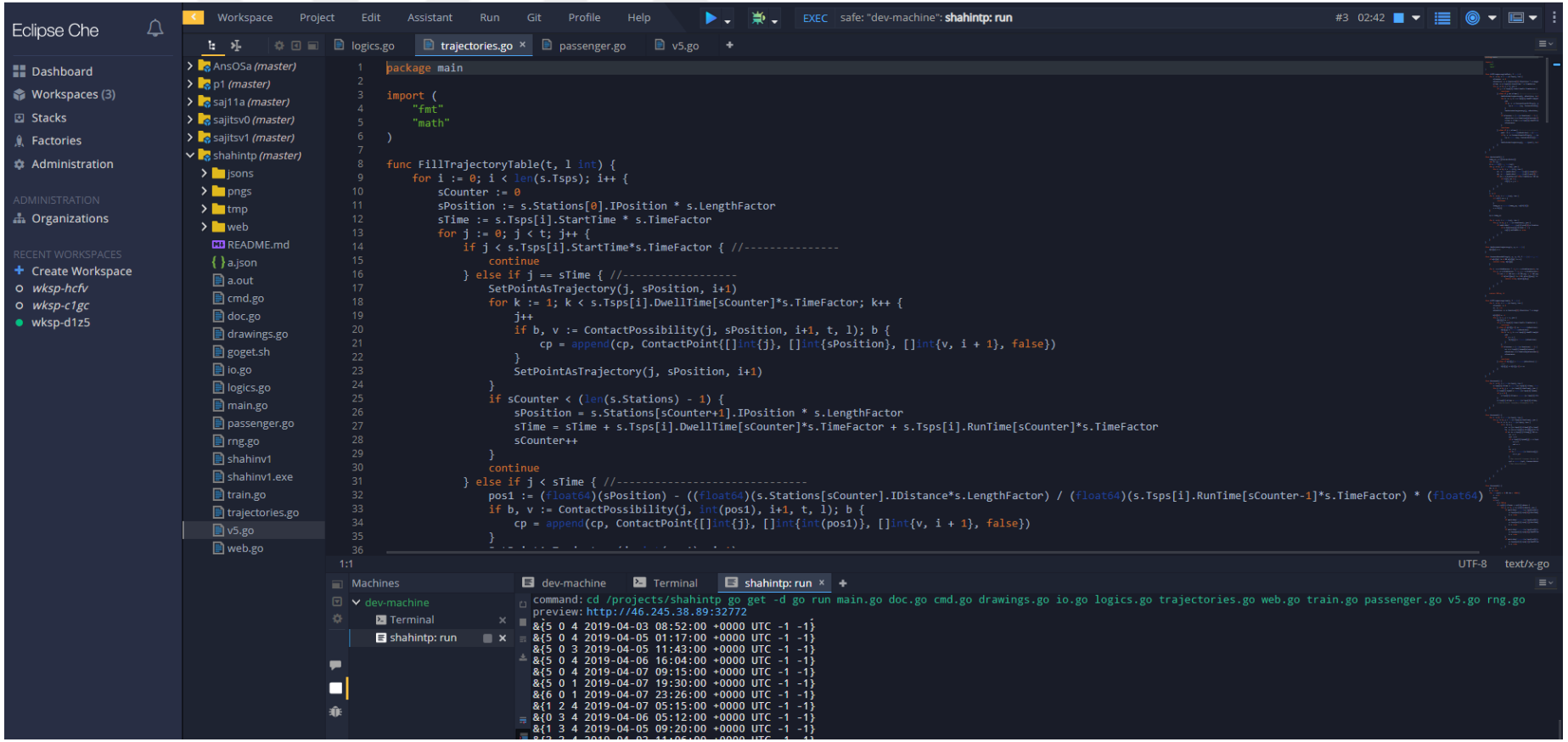

Figure 3.11 : Application of the stations, trains, PTSOs and etc. into the program.

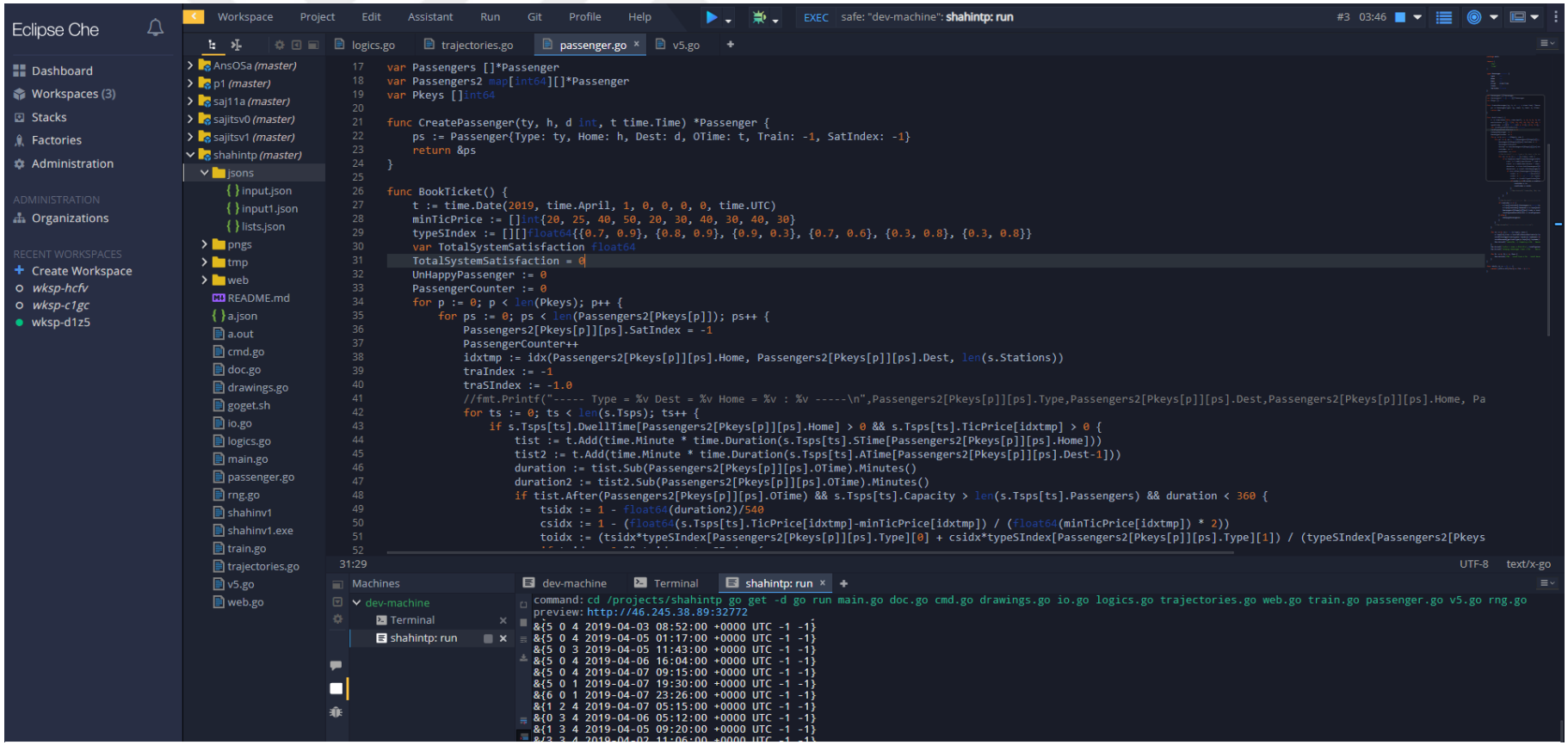

Figure 3.12 : Application of train timetables, PTSOs' proposals, WoT, WoC, PSL and etc. into the program.

In my model I try to fulfill the conditions of the grand coalition. Bargaining problem which was introduced by Nash (1950) is an important element of cooperative games. A bargaining problem is a couple (F,d), where F is the set of feasible outcomes and d is disagreement point. Disagreement point can be considered as starting payoff or the minimum utility that is guaranteed by a player in case they do not reach an agreement. At this point, it is beneficial to present a brief explanation of bargaining problem.

Bargaining can be modeled using game theory. Each side has a range of interests, preferences over outcomes, and the two sides must agree or else neither side gets anything. A bargaining solution is a point that is within the acceptable ranges to both parties. If the two sides have irreconcilable differences, then the negotiation ends in failure. In bargaining problems, it is assumed that the two sides can agree upon some outcomes. The question is which outcome is fair, and which side will get an outcome that is more favorable. There are several solutions to the bargaining problem of Nash. One solution is an approach suggested by Nash himself. Nash advocated that there are a few reasonable rules that should apply to the bargaining and proved that the problem has a unique solution by fulfilling the four conditions of the problem: symmetry, Pareto-efficiency, independence of irrelevant alternatives and invariance to equivalent utility transformation.

The symmetry axiom states that two players should get the same amounts if they both have the same utility function ($u_1 = u_2$), the same disagreement point ($d_1 = d_2$) and the set of feasible outcomes is symmetric (if (x_1, x_2) is feasible so is (x_2, x_1)).

The axiom of Pareto efficiency says that any solution should be efficient. It should not be inefficient with room for improvement to both players. Mathematically, the solution (v_1, v_2) is efficient if there is no other point that is at least as good for both players and strictly better for at least one player.

The independence of irrelevant alternatives axiom states that a preferred solution in a larger set will still be a preferred solution in a smaller subset.

This axiom states that if a point is a solution for some set of utility functions, then it should also be a solution for the utility functions under an affine transformation. The idea is that payoffs are not dependent on the actual numbers but rather the underlying

preferences over outcomes. The idea is that payoffs are not dependent on the actual numbers but rather the underlying preferences over outcomes.

Four axioms given above define a unique solution that maximizes the product of the payoffs over the disagreement point. Simply as follow:

$$\max\ (u_1(x_1) - u_1(d_1))(u_2(x_2) - u_2(d_2)) \tag{3.1}$$

In other words, Nash solution find the unique bargaining solution using the following approach:

$$\mathrm{N}(\mathrm{F}, \mathrm{d}) = \operatorname{argmax} \left\{ \prod_{\mathrm{i} \in \mathrm{N}} (x_i - d_i) \,\middle|\, \mathrm{x} \in \mathrm{F}, \mathrm{x} \geq \mathrm{d} \right\} \tag{3.2}$$

While the Nash bargaining solution is mathematically interesting, there is an issue of how to implement it practically. The two players are supposed to know the feasibility set, disagreement points, and utility functions as common knowledge. If the two players misrepresent details, like their utility functions, for example, then the outcome can change drastically.

Later on, some other scientists tried to cope with this shortage of Nash solution. The major differentiating point was to propose feasible agreements sets and region rather than a unique solution. Kalai-Smorodinsky (1975) presented an approach to equalize the ratios of maximal gains as follow:

$$K\ (F, D) = argmax \left\{ \frac{x_1 - d_1}{a_1 - d_1} = \frac{x_n - d_n}{a_n - d_n} \,\middle|\, x \in F, x \geq d \right\} \tag{3.3}$$

Where $\{a_i = \max x_i \in R\ | x \in F, x \geq d\}, i \in N.$

Another solution to the Nash bargaining problem is Kalai's Egalitarian solution (1977) which tends to maximize the minimum of surplus utilities as follow:

$$E(F, D) = argmax\ \{x_1 - d_1 = \cdots = x_n - d_n | x \in F, x \geq d\} \tag{3.4}$$

In this thesis, I set out to optimize the system as a whole with an approach similar to the Nash solution (1950) to the bargaining game but with an essential difference. Nash bargaining solution proposes a unique solution to resolve every negotiation by fulfilling the four conditions of the equation formerly-given. However, its implementation in real-world and typical negotiations of involved sides of a market

liberalization in railway sector might be objectionable and unrealistic. To cope with this problem, I define a feasible region of solutions rather than one specific solution with regard to the disagreement points of all involved interest groups.

The simulator takes the first step by commencement of the negotiations and solving congestion/scarcity conflicts which was given in previous section. The simulator takes the next step by distributing the passengers to the trains being served by the PTSOs. To do this, the simulator requires some information about passengers as input data. This information includes the passengers' travel preferences, time and cost priorities and socio-economic circumstances. Data acquisition and extraction of required parameters will be presented in the next section of this chapter.

When it comes to the passengers, I developed a criterion called Passenger Satisfaction Level (PSL) to obtain their level of satisfaction with regard to the train services as follow:

$$PSL = \alpha . T + \beta . C \tag{3.5}$$

Where:

T=C=50 (maximum level) time and cost constant values

α = coefficient of timing

β = coefficient of ticket pricing

Other important parameters such as level of comfort for the services and trains, accessibility, parking facilities and etc. can be included in the model in future efforts. The values of α and β are also obtained from the survey and an interpolation of the values which were presented by passengers throughout Excel tools. Six types of passengers (travel purpose), Weight of Time (WoT), Weight of Cost (WoC) and α and β values will be presented in the next section.

Passengers Satisfaction Level (PSL) is a value in the range of [0,100]. A passenger evaluates his/her PSL with regard to two parameters. One is the time of the service which means whether the travel commencement/arrival time of the train which he/she is assigned is suitable or not. If he/she is completely assigned to a train of his/her preferred time span the value of 50 is assigned to that passenger as timing satisfaction. If the time of the assigned train is not acceptable for the passenger at all, he/she assigns value of zero. The same logic is true for cost parameter. If the ticket

price of the train which the passenger is assigned to, is in fully satisfied level, he/she gets the value of 50 and in exact opposite point it gets zero. A PSL of 100 means that the mentioned passenger is fully satisfied with the ticket price and time schedule of the assigned train and a PSL of zero can be obtained in 2 cases: one is that the ticket price is not in his/her range of budget and the second case occurs when he/she cannot depart/arrive at desired time. In these cases, the simulator assigns zero as that passenger's PSL and he/she shift its mode of travel to the other means of travel such as air or highways.

In subsequent step, the simulator calculates the revenues of each train of PTSOs from ticket selling and their expenditures including rolling stock leases, maintenance and repairement costs, staff, energy consumption, payment for stops at stations and TAC and assesses the net revenue for each train. To evaluate the profitability of each train, the simulator gets the initial investment amount of the related PTSO and apply common annual growth rate and compare it to the net earned revenue.

Finally, the simulator evaluates the case of IP by calculating its revenues from collecting TACs and payments for stops at stations and compare it to its expenditures. All calculations for the entire system are on a weekly-based situation. In our model, the disagreement point for a PTSO occurs when the net revenue earned from train operations remains under the anticipated net revenues which would have been earned by applying the annual growth rate of the markets in Turkey. Our simulator considers a one-year lease costs as a PTSO's initial capital and calculates an annual growth rate of 10% on that basis. In fact, interest rates on deposits in Turkey have remarkably fluctuated during economic crises. For example, it has experienced a sudden increment to annual rate of 30% in 2001 crisis. After the removal of the crisis effect, it has faced a long-term steady state fluctuating between 5.75 to 15%. Again from 2018 on, an unsteady case is dominating the markets in Turkey with severe increments in interest rates. Recently, strict measurements have been taken to control this issue. However, the average rate from the beginning of 2000s is around 10%. Thus, the amount to be evaluated by the simulator has been selected in this manner. This amount is calculated based on a 1-year leasing costs of the rolling stock, since the PTSO pay for it at the beginning of the contract. Other expenditures such as rentals, TAC and salaries are not paid in this context. As for public agent, the simulator calculates the revenues related to TAC and waiting at

stations from the PTSOs and controls whether it covers the IP's expenditures or not. The public agency also preserves passengers' rights and takes their concerns into consideration. In this context, a comprehensive agreement may be reached while PSL is 100 for at least half of the passengers and average PSL of the system (all passengers on hand) is over 90.

The following suppositions have been regarded in the simulator:

- 20% and 50% discount for students and 65+ passengers, respectively.
- 25% more ticket price for VIP.
- 15-20% type 5 passengers 65+
- 15-20% type 3 passengers VIP
- Leasing duration for rolling stock: 10 years dry leasing
- Leasing cost for PTSOs = whole life price / 2.5
- One-year leasing payment is done by PTSOs at very first moment.
- 4 trip / one train set / day for PTSOs
- PTSOs' desired minimum growth rate = 10%
- Boarding only considered in 1st station
- Maximum flexibility of T_D at stations for PTSOs = 5 min
- Maximum flexibility of speed for PTSOs' trains = 10% of preferred initial speed
- Trains can bypass at stations. In all other cases they have to be at least in a 5-km distance from other trains on the track.
- Typology of passengers: Stochastic
- €/TL = 4.5 (at the commencement of thesis preparation period)

3.5 Stated Preference Survey and Data Acquisition

In our model, as was illustrated in Figure 3.9, subsequent to the negotiation process and allocation of capacity, passenger distribution is being applied and passengers are assigned to the trains with regard to their time and ticket price preferences. To do

this, the simulator requires some information about passengers as input data. This information includes the passengers' travel preferences, time and cost priorities and socio-economic circumstances. A Stated Preference (SP) survey of 191 participants was conducted in Pendik train station, Istanbul, to use as passengers' data in the simulation. The questionnaire is presented in Appendix A. The case study of this thesis is inspired by Istanbul-Ankara HSR line where Pendik is the first and most important boarding station in Istanbul-Ankara direction and the data collected from passengers at this station can provide the simulator more realistic input. SP surveys aim at collecting replies to hypothetical cases presented to users of the system (Cascajo and Garcia-Martinez, 2017; Petrik et al, 2016; Hensher, 1994), in our case, rail passengers.

The questionnaire includes the data related to participants' demography, individual and household income, gender, profession, age, education, car ownership, residential place in Istanbul, destination, purpose of trip, paid price for ticket, frequency of this trip, day preference of the trip (weekend/weekday), travel time preference during day in 2-hour spans commencing from 06:00-08:00 in the morning to 22:00-24:00. The major goal of the survey was to obtain passengers' weight of Time (WoT) and Weight of Cost (WoC). To do this, passengers had to attach a value from 1 to 10 to each of WoT and WoC and these values were also cross-examined by offering predetermined travel alternatives. A passenger with a value of 10 for WoT is highly sensitive to time scheduling of the train (in most cases arrival time). Students who are travelling to attend their classes, passengers with commercial purposes and those who are travelling to Ankara to deal with their administrative affairs were observed to be in this populace. Getting closer to the value of 1 for WoT implies that timing is not that important for that specific passenger. For instance, a 65^{+} passenger who is willing to travel to visit relatives is somehow indifferent in selecting travel time since the departure/arrival time may not play a crucial role for him/her. In a similar manner, a passenger with WoC of 1 is exactly opposed to pay more for ticket price and he/she may change his trip mode if the price remains over his/her tolerable rate. In contrast, a passenger with WoC of less values is indifferent to ticket price and the travel time and quality is the only regarded matter. These values would be logged into the system in analysis stage. Furthermore, the passengers would be distributed in the system with regard to their preferences on the days and time period during the

day. Based on the results of the survey, it was decided to classify the passengers into six major groups with different WoT and WoCs which are presented in Table 3.3.

Table 3.3 : Passenger classification in the model and the values of WoT and WoC.

Passenger type	WoT	WoC
1	[7,9]	[7,9]
2	[8,9]	[7,9]
3	[7,9]	[4,6]
4	[7,8]	[6,8]
5	[4,7]	[6,9]
6	[5,8]	[7,9]

WoT and WoC show the passengers' concentration and prioritization on travel time (departure/arrival) and ticket costs. Some additional graphics and data related to the survey and extraction of α and β values are given in Appendix B .

In Table 3.3, Type 1 represents the passengers who are students travelling from departure station, "A", to the destination, "E" with purposes other than going to the universities. Indeed, our model includes five stations from "A" to "E" which denote Istanbul and Ankara, respectively and we only consider the boarding in Istanbul and unboarding in Ankara, due to simulation simplicity. In future work, I may improve the model for more complex network with boarding and unboarding in all stations. Type 2 passengers are students who are traveling due to educational purposes and participating in the classes. For both types 1 and 2 a %20 discount in ticket prices is regarded based on their studentship. Type 3 passengers are those who are traveling from "A" due to commercial purposes. Type 4 represents the passengers who are traveling from "A" due to administrative affairs. Type 5 represents the passengers who are not students and traveling from "A" to visit family and relatives. This group is separated from 1^{st} type since there is not a discount for passengers of this group who are under 65 years old. For 65+ passengers, there is a %50 discount level in ticket prices and it was observed that almost %20 of this group's passengers are 65^{+}. The last type represents the passengers traveling from "A" due to touristic purposes. Using the values obtained from the survey (Table 3.3), we will obtain α and β values of Equation 3.5 in Table 3.4 and Table 3.5.

Table 3.4 : α value for passengers with various WoTs.

Variance from passengers' preferred travel time span (min)	WoT					
	9	8	7	6	5	4
$5 < {}^{*}t_v \leq 15$	0.85	0.90	0.95	1	1	1
$15 < t_v \leq 30$	0.75	0.85	0.90	0.95	1	1
$30 < t_v \leq 45$	-	0.80	0.85	0.90	0.95	1
$45 < t_v \leq 60$	-	-	0.80	0.85	0.90	0.95
$60 < t_v \leq 75$	-	-	-	0.80	0.85	0.95
$75 < t_v \leq 90$	-	-	-	0.75	0.80	0.90
$90 < t_v \leq 105$	-	-	-	-	0.80	0.85
$105 < t_v \leq 120$	-	-	-	-	0.75	0.80
$120 < t_v \leq 135$	-	-	-	-	0.70	0.75
$135 < t_v \leq 150$	-	-	-	-	0.65	0.75
$150 < t_v \leq 165$	-	-	-	-	-	0.70
$165 < t_v \leq 180$	-	-	-	-	-	0.65
$180 < t_v \leq 195$	-	-	-	-	-	0.60
$195 < t_v \leq 210$	-	-	-	-	-	0.55

*t_v = time variance between passengers' preferred train and existing train.

Table 3.5 : β value for passengers with various WoCs.

Ticket price span (TL)	WoC					
	9	8	7	6	5	4
≤70	1	1	1	1	1	1
70<Pt ≤75	0.9	0.95	1	1	1	1
75<Pt ≤80	0.85	0.9	0.95	1	1	1
80<Pt ≤85	0.8	0.85	0.90	0.95	1	1
85<Pt ≤90	-	0.8	0.85	0.90	0.95	1
90<Pt ≤95	-	-	0.80	0.85	0.9	0.95
95<Pt ≤100	-	-	075	0.80	0.85	0.9
100<Pt ≤105	-	-	-	0.75	0.8	0.85
105<Pt ≤110	-	-	-	-	0.75	0.8
110<Pt ≤115	-	-	-	-	0.7	0.75
115<Pt ≤120	-	-	-	-	-	0.7
120<Pt ≤125	-	-	-	-	-	0.65
125<Pt ≤130	-	-	-	-	-	-

Total number of passengers participated in the survey based on their travel type are 51, 23, 23, 36, 42 and 16 for types 1 to 6, respectively. Age average for the respondents of mentioned types are 22, 26, 41, 37, 57 and 26, respectively. Percentage of the passengers had reached the Pendik station using at most two means of transport (including private and public transport) is around 82%. Average household size for entire group is 3.2 ranging between 1 and 6. The number of passengers who use the line once in a while is 132. The number of passengers who use the line in monthly routines is 46 and those who use the line in weekly-based

routines is 13 where almost all of them are students. 124 passengers stated that their preferred time span for travel is during the peak hours (06:00-10:00 and 16:00-19:00). Remaining 67 passengers are either indifferent to the time (mostly elderly respondents of Type 5) or prefer to travel in a span out of the peak hours. The number of passengers with car ownership of zero, 1 and 2 in the household are 68, 113 and 10, respectively. However, car ownership of zero and 1 for the passengers themselves (self-ownership rather than entire family) are 129 and 62, respectively.

As was mentioned before, PSL of a passenger is a parameter developed by our model to measure the satisfaction level and has two criteria. One is related to time scheduling. The maximum PSL is 100 which can be obtained by 50 point from time scheduling of the train and 50 by cost preference. It was mentioned that a passenger which is assigned to a train in his totally preferred time span gets the value of 50 ($\alpha T=1\times50$). α and β values have been derived in a simple manner. To do this, the minimum and maximum values for the passengers of a definite WoT or WoC are considered as the border values. The topmost value(s) amount among all values of a specific WoT or WoC group is considered as the accepted value for all of the passengers in that classification with a rate of 1 and a reduction and increment of 0.05 for α and β is applied for the values over and under the accepted values, respectively. Passengers have a toleration range for timing and this range is tested by α value. In Table 3.4 it is observed that a time-sensitive passenger of WoT=9 can tolerate a maximum level of 30-min delay in his/her preferred travel time and the value of α gets lower rates by having delay up to 30 minutes. If such a passenger is assigned to a train which has a variance of more than 30- min compared to his/her preference, the passenger is being put away from the system and a PSL of zero is assigned to him/her. As for ticket price, current ticket price of 70 TL for Istanbul-Ankara is considered as base point. In this context, a passenger of WoC=9 can tolerate a maximum level of 85 TL as ticket price where every 5 TL increment in price reduces his/her β value and therefore PSL. If such a passenger is not assigned to a train with a price of less than 85 TL, he/she would shift his/her travel mode and gets a value of zero for the PSL. The method for extraction of α and β values in Table 3.4 and Table 3.5 is presented in Appendix C.

4. SIMULATION RESULTS AND POLICY ANALYSIS

A hypothetical open railway access market similar to the Istanbul-Ankara line has been set up to demonstrate the applicability of the model. This market consists of one IP which is the provider of the infrastructure (in my case, TCDD, who tends to liberalize the market and provide an open access for PTSOs) and six PTSOs while the railway services cover five stations with a total distance of 550 Km for Istanbul-Ankara, including Istanbul. Gebze, Izmit, Eskisehir and Ankara to be denoted by (A, B, C, D and E), respectively. The details of the interstation distances are given in Table 4.1. However, the values are not exactly equal to the existing distances and are rounded to the nearest 25-km. Afterwards, the initial proposals of the PTSOs and their results will be presented. In subsequent steps, three alternative scenarios and policy analyses will be evaluated to improve the utilization and effectiveness of the rail system.

Table 4.1 : Inter-station distances.

Origin	Destination	Inter-station distance (km)
A	B	25
B	C	50
C	D	225
D	E	250

4.1 First Scenario (PTSOs' Initial Proposals)

The details of the PTSOs' initial scheduling and proposals are given in Table 4.2 with information about the time for approaching the platform, dwell time, inter-station runtime and accepted rate of TAC to be paid to the IP.

As is clear from Table 4.2, PTSO1 and 2 and 3 have two train services during the day: one in the morning and the other in evening. To clarify Table 4.2, the case of PTSO2-1 is explained here. This train is the morning train of PTSO 2. It arrives at Pendik station in Istanbul at 06:30 to board the passengers.

Table 4.2 : Initial proposals of the PTSOs.

ID	PTSO1-1	PTSO2-1	PTSO3-1	PTSO4	PTSO5	PTSO6	PTSO1-2	PTSO2-2	PTSO3-2
ξ	06:15	06:30	08:30	08:00	11:00	23:45	17:00	16:00	15:00
T_D (min)	30, 0, 0, 0, 15	30, 5, 5, 15, 15	30, 0, 0, 15, 15	30, 5, 5, 10, 15	30, 5, 5, 10, 15	15, 0, 0, 0, 10	30, 0, 0, 15, 15	30, 5, 5, 15, 15	30, 0, 0, 15, 15
T_R (min)	150	15, 20, 75, 83	90, 75	15, 20, 75, 83	17, 25, 83, 88	412	82, 68	15, 20, 75, 83	90, 75
AC-TAC (TL)	13,750	12,100	12,100	11,000	5,500	2,750	13,750	7,150	6,600

The dwell time is 30, 5, 5, 15 and 15 minutes at stations Istanbul, Gebze, Izmit, Eskisehir and Ankara, respectively. Runtime between Istanbul-Gebze, Gebze-Izmit, Izmit-Eskisehir and Eskisehir-Ankara are 15, 20, 75 and 83 minutes respectively. As for accepted-TAC for this PTSO, they accept to pay 12,100 TL for their initial proposal (one Istanbul-Ankara trip).

First of all, the program searches for the possible conflicts in PTSOs' proposed schedules on the trajectory. The program recognizes some conflict points on the trajectory between trains 1-1vs 2-1, 3 vs 4 and 1-2 vs 2-2. Table 4.3 summarizes the required changes in timetable to avoid conflicts which is obtained from the trajectory provision of the code prepared by GoLang in Figure 4.1.

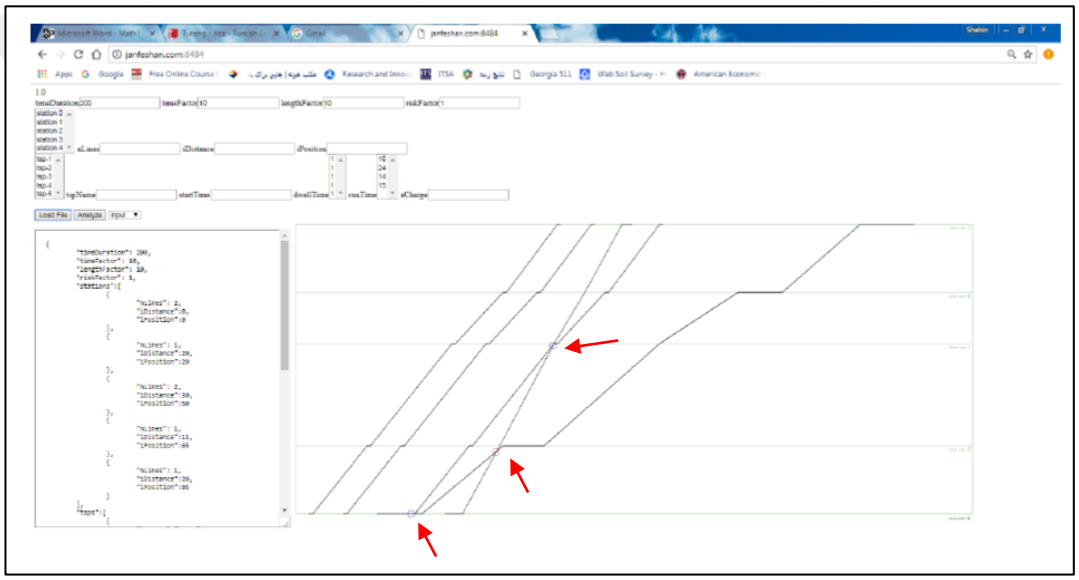

Figure 4.1 : Conflict points on trajectory.

Table 4.3 : Required changes to avoid timing conflicts.

Train ID	Required changes
PTSO 1-1	Leave station "A" 5 min earlier
PTSO 1-1	Slow down the speed from 220 to 200 km/h between D-E stations.
PTSO 2-1	Leave station "A" 5 min later
PTSO 2-1	Higher up the speed from 180 to 195 km/h between D-E stations
PTSO3	Speed up to 210 km/h between A-D stations
PTSO4	Leave 5 more minutes at station "C"

Secondly, the program has to distribute the passengers in the system. It is supposed that the demand for this line would be between 35,000 and 40,000 passengers during the week. The simulator selects a random value in the given range where in this case that value is 38,243 passenger/week. Based on the information obtained from the

survey and percentage of the passenger types, the following values have been randomly selected by the simulator as the number of passengers with their types (daily-based): 1097, 552, 834, 1366, 1110, 504 for Type 1 passengers to Type 6, respectively. These values will be the same for all the scenarios in order to have a fair comparison among them. PTSO1 has the most developed rolling stock with the highest lease costs and I suppose that PTSO 6 mainly operates trains for other origin-destination trips on this track and only wants not to idle a part of its fleet after 19:00 each day.

To test the simulator's power in evaluation process, I have presented 4 case scenarios. The first case is PTSOs' initial proposal which was given in Table 4.2. In this scenario, the major focus of the train scheduling is given for peak hours (06:00-10:00 & 16:00-19:00) and there is a remarkable gap during mid-day. Besides, the capacity of the trains (supply) is far less than the demand for trip during the week. The ticket prices are also remarkably high compared to the base level of 70 TL. In second case scenario, a 10-TL reduction in expensive trains (PTSO1,2,3) is applied with the same capacity for trains. In third case, the prices are the same with case 2 but the capacity is 1.5 folded for trains in peak hours period by adding 4 wagons to them. By doing this, the capacity meets the requirements of the demand. In 4^{th} case, the capacity is the same with case 3 but the prices are also justified. While conducting the survey, it was observed that 100 TL is the psychologic frontier; thus, price adjustments are done on such a base. Ticket prices (Istanbul-Ankara) for each scenario and PTSOs1-6 are given in Table 4.4. At this point, it should be noted that for the first scenario the ticket fares of most PTSOs are far higher than existing level of ticketing. Furthermore, the capacity cannot meet the requirements of the passengers willing to travel by train. In the second scenario, I want to make a reduction in ticket fares for those PTSOs with rates of higher than 100 TL which was observed as a psychological limit for the passengers. In the third scenario, I try to increase the capacity of the trains during the week with the same ticket fares of the second scenario. Finally, I fix the fares to a reduced level for all PTSOs, fix the capacity problems and distribute the trips in a logical manner to cover all time spans during a day. The simulator will inform us about the advantages and disadvantages of these strategies in a multi-objective manner based on the goals of the IP, PTSOs and passengers.

Table 4.4 : Trains' ticket prices for 4 scenarios.

PTSO ID	Scenario 1	Scenario 2	Scenario 3	Scenario 4
PTSO 1	120	110	110	80
PTSO 2	100	90	90	80
PTSO 3	110	100	100	80
PTSO 4	80	80	80	80
PTSO 5	85	85	85	80
PTSO 6	70	70	70	80

At this step, we want to distribute 38,243 passengers/week (in all 4 scenarios) who are willing to use the rail mode for their A-E trip. Due to the simplicity of the program, and the insignificant volume of demand for the stations in-between (B, C, and D), the passengers who embark and drop off are disregarded in these stations. Based on the information obtained from the survey, the typology of the passengers during a week is as follow: 7679, 3864, 5838, 9562, 7770, 3530 for type 1 passengers to type 6 passengers, respectively.

The general case for firms' initial proposals is presented in Table 4.5. Table 4.6 summarizes PTSOs' case of profitability. The data for passengers satisfaction level is given in Table 4.7. When it comes to the public entity, IP collects 645,260 TL per week from PTSOs where its expenditures are around 740,000 (maintenance, repairment) + 20,000 TL/week (staff) = 760,000 TL.

Table 4.5 : Evaluation of the firms cases for the first scenario.

Train ID	Train capacity (seats)	Sold tickets per week	Vacancy per week	Ticket income per week	Costs per week	Net revenue
PTSO 1-1	510	189	3,381	22,680	275,167	-252,487
PTSO 2-1	519	1,967	1,666	191,100	206,798	-15,698
PTSO 3-1	519	1,477	2,156	158,235	213,231	-54,996
PTSO 4	430	3,010	0	221,200	202,034	19,166
PTSO 5	299	2,093	0	170,464	156,650	13,814
PTSO 6	440	833	2,247	50,568	112,990	-62,422
PTSO 1-2	510	315	3,255	35,280	275,167	-239,887
PTSO 2-2	519	1,288	2,345	122,150	206,798	-84,648
PTSO 3-2	519	819	2,814	88,550	213,231	-124,681

In Table 4.6 it is clear that the only profitable trains are PTSO 4 and 5. To evaluate this matter, our program considers the initial investment capital of firms and makes a calculation of annual growth rate of 10% and degrades it to a weekly level. In this context, for example PTSO4 has to earn at least 6,577 TL/week as net revenue to

remain in the system. Finally, Table 4.7 claims that the passengers are almost unsatisfied with the system. First of all, there is a 8,388 gap between demand and supply which means that in the best scenario, 8,388 passengers will not find a seat to travel. It is also clear that even nearly 60% of the existing capacity (seats) are unpurchased by passengers due to high prices or trains' mal-time-scheduling (almost all trains are scheduled for early in the morning and for evening and during the mid-day there is no train). Around 69% of passengers have to change their travel mode dur to lack of adequate capacity, high ticket prices or timing problems. Only 78 passengers out of 38,243 are totally satisfied with their assigned trains and get the PSL value of 100 which means a very small portion of passengers can find trains in their preferred time and on budget. 26,252 passengers have shifted to other modes since the trains are not appropriate for their timing/cost situation and these passengers get the value of zero for PSL. The remaining passengers are assigned to the trains but not fully satisfied and they get a value less than 100. The average PSL value for all 38243 passengers is 24.14 per 100 which means the general grade of the system is too low and not acceptable.

Table 4.6 : Profitability of the train services in the 1st scenario.

Train ID	Weekly net revenues	Min amount to be earned	Profitability
PTSO1-1	-252,487	11,770	NP
PTSO2-1	-15,698	6,231	NP
PTSO3-1	-54,996	6,923	NP
PTSO4	19,166	6,577	P
PTSO5	13,814	5,538	P
PTSO6	-62,422	3,462	NP
PTSO1-2	-239,887	11,770	NP
PTSO2-2	-84,648	6,231	NP
PTSO3-2	-124,681	6,923	NP

Table 4.7 : PSL of the passengers in the 1st scenario.

Parameters	Values
Passengers to be distributed / week (PTBD)	38,243
Supply / week	29,855
Supply/PTBD	0.78
Vacancy / week	17,864
Vacancy/Supply	0.60
Ratio of passengers shifting their travel mode	0.69
Avg. PSL of passengers (per 100)	24.14
No. of passengers with PSL of 100	78
No. of passengers with PSL of 0	26,252
No. of passengers with PSL in-between.	11,913

In NTU cooperative game there is a disagreement point for each party, also known as threat point, in which no agreement would be reached with regard to the payoff levels. In our model, the disagreement point for a PTSO occurs when the net revenue earned from train operating remains under that of anticipated rate of growth for initial investment capital (assumed to be %10 per year). Our simulator considers a one-year lease costs as PTSO's initial capital and calculates growth rate on that basis. As for public party, the simulator calculates the revenues related to TAC and waiting at stations from PTSOs and controls whether it covers at least half of the expenditures or not. Public party also preserves passengers' rights takes their concerns into consideration. In this context, a comprehensive agreement may be reached while PSL is one for at least half of the passengers and total PSL of the system is over 90. With these criteria, it is shown that the first scenario totally fails to fulfill the requirements.

4.2 Second Scenario

In the first scenario it was clear that the PTSOs' high rates of ticket prices act as an obstacle to attract the passengers. In the second scenario, policy analyzers tend to evaluate the effects of lowering the prices of firms whose ticket prices are 100 TL or more. The ticket prices for this scenario were given in Table 4.4. Table 4.8 summarizes the information related to the trains and the passengers in this case. Table 4.9 evaluates PTSOs' profitability. Passengers' case is also given in Table 4.10. For instance, it can be observed that a 10-TL reduction in ticket price of PTSO1-1 has attracted some more passengers. Anyway, this strategy falls far behind

of the firm's profitability since 110 TL ticket price is still being perceived very high by most passengers.

Table 4.8 : Evaluation of the firms cases for the second scenario.

Train ID	Train capacity (seats)	Sold tickets per week	Vacancy per week	Ticket income per week	Costs per week	Net revenue
PTSO 1-1	510	651	2,919	73,304	275,167	-201,863
PTSO 2-1	519	3,206	427	299,880	206,798	93,082
PTSO 3-1	519	2,814	819	246,400	213,231	33,169
PTSO 4	430	3,010	0	216,755	202,034	14,721
PTSO 5	299	2,093	0	168,196	156,650	11,546
PTSO 6	440	812	2,268	49,098	112,990	-63,892
PTSO 1-2	510	1,197	2,373	131,824	275,167	-143,343
PTSO 2-2	519	2,779	854	244,125	206,798	37,327
PTSO 3-2	519	1,715	1,918	169,750	213,231	-43,481

Table 4.9 : Profitability of the train services in the 2nd scenario.

Train ID	Weekly net revenues	Min amount to be earned	Profitability
PTSO1-1	-201,863	11,770	NP
PTSO2-1	93,082	6,231	P
PTSO3-1	33,169	6,923	P
PTSO4	14,721	6,577	P
PTSO5	11,546	5,538	P
PTSO6	-63,892	3,462	NP
PTSO1-2	-143,343	11,770	NP
PTSO2-2	37,327	6,231	P
PTSO3-2	-43,481	6,923	NP

Table 4.10 : PSL of the passengers in the 2nd scenario.

Parameters	Values
Passengers to be distributed / week (PTBD)	38,243
Supply / week	29,855
Supply/PTBD	0.78
Vacancy / week	11,578
Vacancy/Supply	0.39
Ratio of passengers shifting their travel mode	0.52
Avg. PSL of passengers (per 100)	37.22
No. of passengers with PSL of 100	127
No. of passengers with PSL of 0	19,966
No. of passengers with PSL in-between.	18,150

PTSO1-1, 6, 1-2, and 3-2 are in loss yet, since their net revenues do not meet the 10% annual growth rate condition. This price reduction has attracted 17% more

passengers (in former scenario 69% of passengers shifted their mode but here 52% do this) and increased average PSL of all 38,243 passengers from 24.14 to 37.22. This implies that even a small reduction in prices is able to attract passengers in a serious rate.

4.3 Third Scenario

In the 3rd case, I want to cope with the problem of capacity. In first two cases, the weekly supply was seriously (8,388) under the ridership. In this scenario, I will increase the supply with the same prices with scenario 2 to see the results. Here, I decide to increase the capacity of trains to 1.5 times by adding four wagons for trains during peak hours (06:00-10:00 & 16:00-19:00). The results for PTSO evaluation is presented in Table 4.11. Table 4.12 evaluates general profitability of the PTSOs. PSL of passengers for this case is also given in Table 4.13. As for public side, this time IP collects 733,810 TL/week from PTSOs for TAC and stops at stations which is close to its expenditures.

Table 4.11 : Evaluation of the firms cases for the third scenario.

Train ID	Train capacity (seats)	Sold tickets per week	Vacancy per week	Ticket income per week	Costs per week	Net revenue
PTSO1-1	765	868	4,487	96,096	316,033	-219,937
PTSO2-1	778	5,446	0	434,070	231,306	202,764
PTSO3-1	778	4,123	1,323	360,150	238,778	121,372
PTSO4	645	4,515	0	315,000	234,761	80,239
PTSO5	299	2,093	0	157,374	156,650	724
PTSO6	440	441	2,639	29,596	112,990	-83,394
PTSO1-2	765	1,561	3,794	171,710	317,608	-145,898
PTSO2-2	778	5,180	266	415,800	192,806	222,994
PTSO3-2	519	1,491	2,142	144,550	174,731	-30,181

Table 4.12 : Profitability of the train services in the 3rd scenario.

Train ID	Weekly net revenues	Min amount to be earned	Profitability
PTSO 1-1	-219,937	14,711	NP
PTSO 2-1	202,764	7,788	P
PTSO 3-1	121,372	8,654	P
PTSO 4	80,239	8,221	P
PTSO 5	724	6,923	NP
PTSO 6	-83,394	3,462	NP
PTSO1-2	-145,898	14,712	NP
PTSO2-2	222,994	7,788	P
PTSO3-2	-30,181	6,923	NP

Table 4.13 : PSL of the passengers in the 3rd scenario.

Parameters	Values
Passengers to be distributed / week (PTBD)	38,243
Supply / week	40,369
Supply/PTBD	1.06
Vacancy / week	14,826
Vacancy/Supply	0.37
Ratio of passengers shifting their travel mode	0.39
Avg. PSL of passengers (per 100)	48.45
No. of passengers with PSL of 100	155
No. of passengers with PSL of 0	14,826
No. of passengers with PSL in-between.	23,262

Table 4.11 still shows that for trains with ticket prices of higher than 100 TL, the capacity is not the matter, since despite the capacity increment the majority of the train is empty. This strongly urges the related PTSOs to take required measurements and change their policies. Otherwise, they cannot survive in this market. From Table 4.12, it is clear that more than half of the trains are not profitable. Capacity increment has increased average PSL from 37.22 to 48.45 but again it is far from our program's accepted criteria which requires the system to offer such a system in which all PTSOs are profitable, at least half of the passengers have the PSL of 100 and average PSL of all passengers should be more than 90.

4.4 Fourth Scenario

In the 4th case, I do not change the logic behind the supply of the 3rd scenario but instead lower the prices and fix all PTSOs' prices to 80 TL. On the other hand, I try to distribute the train services all day long rather than some congested plans during

peak hours. To do this, Table 4.14 presents the alterations in PTSOs times scheduling and Table 4.15, Table 4.16 and Table 4.17 evaluate the results from the perspectives of PTSOs and firms.

Table 4.14 : Time scheduling of the PTSOs in the 4th scenario.

ID	PTSO 1-1	PTSO 2-1	PTSO 3-1	PTSO 4	PTSO 5	PTSO 6	PTSO 1-2	PTSO 2-2	PTSO 3-2
ξ	06:15	07:00	09:15	08:00	11:00	19:15	16:00	14:30	12:30
T_D (min)	30, 0, 0, 0, 15	30, 5, 5, 15, 15	30, 0, 0, 15, 15	30, 5, 5, 10, 15	30, 5, 5, 10, 15	15, 0, 0, 0, 10	30, 0, 0, 15, 15	30, 5, 5, 15, 15	30, 0, 0, 15, 15
T_R (min)	150	15, 20, 75, 83	90, 75	15, 20, 75, 83	17, 25, 83, 88	330	82, 68	15, 20, 75, 83	90, 75
AC-TAC (TL)	27,500	27,500	27,500	27,500	13,750	13,750	27,500	13,750	13,750

Table 4.15 : Evaluation of the firms cases for the fourth scenario.

Train ID	Train capacity (seats)	Sold tickets per week	Vacancy per week	Ticket income per week	Costs per week	Net revenue
PTSO1-1	778	5,152	294	396,480	335,000	61,480
PTSO2-1	778	5,054	392	392,560	327,556	65,004
PTSO3-1	778	5,355	92	407,120	335,027	72,093
PTSO4	645	4,361	154	345,800	331,011	14,789
PTSO5	430	3,010	0	230,160	214,400	15,760
PTSO6	440	3,080	0	231,000	189,990	41,010
PTSO1-2	765	5,187	167	387,520	335,000	52,520
PTSO2-2	519	3,507	126	270,200	218,348	51.852
PTSO3-2	519	3,535	98	272,440	224,781	47,659

Table 4.16 : Profitability of the train services in the 4th scenario.

Train ID	Weekly net revenues	Min amount to be earned	Profitability
PTSO1-1	61,480	8,650	P
PTSO2-1	65,004	7,788	P
PTSO3-1	72,093	8,653	P
PTSO4	14,789	8,221	P
PTSO5	15,760	6,577	P
PTSO6	41,010	3,461	P
PTSO1-2	52,520	8,650	P
PTSO2-2	51.852	7,962	P
PTSO3-2	47,659	6,923	P

Table 4.17 : PSL of the passengers in the 4th scenario.

Parameters	Values
Passengers to be distributed / week (PTBD)	38,243
Supply / week	39,564
Supply/PTBD	1.03
Vacancy / week	1,323
Vacancy/Supply	0.03
Ratio of passengers shifting their travel mode	0
Avg. PSL of passengers (per 100)	94.18
No. of passengers with PSL of 100	21,126
No. of passengers with PSL of 0	2
No. of passengers with PSL in-between.	17,115

It should be noted that in this scenario, PTSO1 has changed its train sets and uses the rolling stock similar to PTSOs 2 and 3 which is more economical. Table 4.15 shows that all passengers have found a train compatible with their preferences. Despite a remarkable reduction in ticket prices for trains, all PTSOs are profitable in this case

with regard to Table 4.16. 21,126 of passengers which is more than half, get the value of 100 for their PSL that implies they are totally pleased with the system (based on both timing issues and budget) and average PSL for all 38,243 passengers is 94.18 which is a very high value and is in feasible region of our program. Thus, case 4 shows us that a budget price for ticketing, proper capacity consideration and appropriate time scheduling of trains can lead to a very successful privatized rail market in which passengers are pleased, PTSOs make great profits and the IP can collect remarkable amount as TAC to invest in infrastructure. Finally, the IP (TCDD) collects 1,399,860 TL/week from PTSOs where its far more than the expenditures (760,000 TL/week) and they can invest in developing the infrastructure and providing new services.

4.5 Recapitulation of the Scenarios

Table 4.18, Table 4.19 and Table 4.20 summarize the information and results for all PTSOs, passengers and IP for all four scenarios, respectively. Graphical illustration of the results for the PTSOs in different scenarios and IP are also given in Figure 4.2-Figure 4.10

Table 4.18 : Profitability of the train services in all scenarios.

ID	PTSO 1-1	PTSO 2-1	PTSO 3-1	PTSO 4	PTSO 5	PTSO 6	PTSO 1-2	PTSO 2-2	PTSO 3-2
scenario 1	N.P.	N.P.	N.P.	P.	P.	N.P.	N.P.	N.P.	N.P.
scenario 2	N.P.	P.	P.	P.	P.	N.P.	N.P.	P.	N.P.
scenario 3	N.P.	P.	P.	P.	N.P.	N.P.	N.P.	P.	N.P.
scenario 4	P.	P.	P.	P.	P.	P.	P.	P.	P.

Table 4.19 : PSL of the passengers in all scenarios.

Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Passengers to be distributed / week (PTBD)	38,243	38,243	38,243	38,243
Supply / week	29,855	29,855	40,369	39,564
Supply/PTBD	0.78	0.78	1.06	1.03
Vacancy / week	17,864	11,578	14,826	1323
Vacancy/Supply	0.60	0.39	0.37	0.03
Ratio of passengers shifting their travel mode	0.69	0.52	0.39	0
Avg. PSL of passengers (per 100)	24.14	37.22	48.45	94.18
No. of passengers with PSL of 100	78	127	155	21,126
No. of passengers with PSL of 0	26,252	19966	14,826	2
No. of passengers with PSL in-between.	11,913	18150	23,262	17115

Table 4.20 : IP's revenues from the PTSOs.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
TAC and dwelling revenues collected by the IP from the PTSOs	645,260	645,260	733,810	1,399,860

Figure 4.2 to Figure 4.10 illustrate the profitability of the trains and PTSOs. The line(s) on each figure shows the minimum amount to be earned by the PTSO.

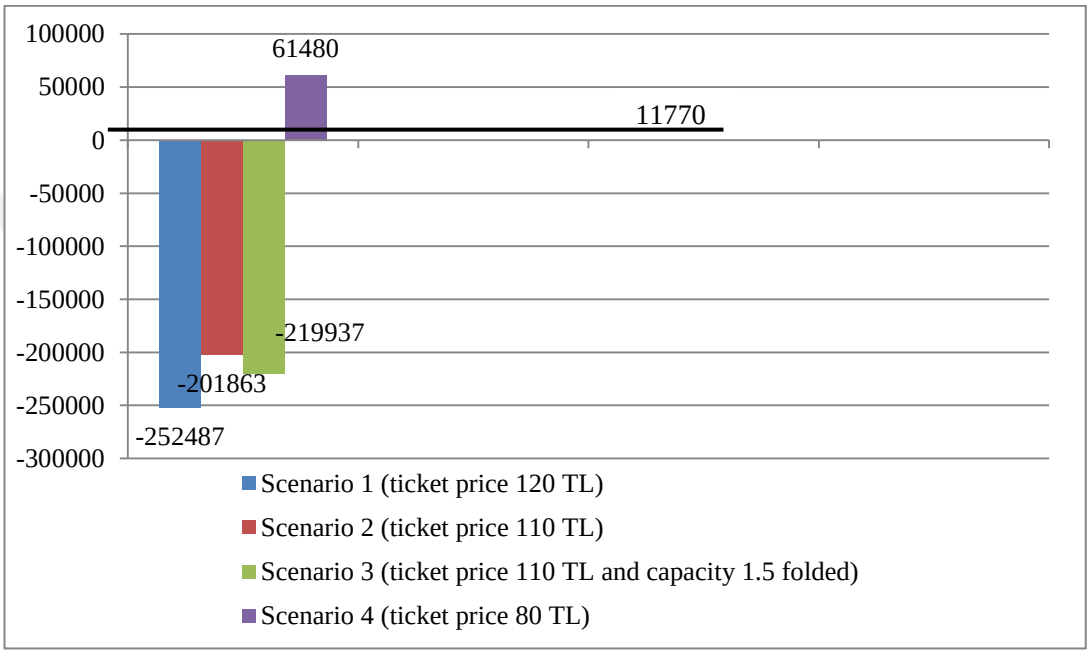

Figure 4.2 : Net weekly profit/loss of PTSO 1-1 in different scenarios in TL.

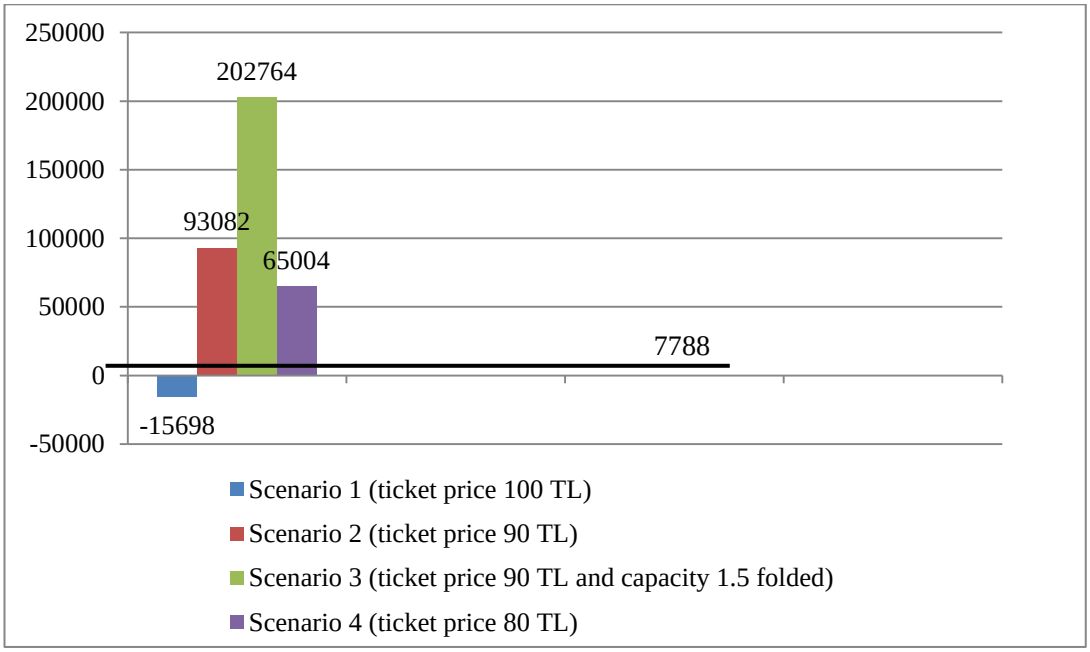

Figure 4.3 : Net weekly profit/loss of PTSO 2-1 in different scenarios in TL.

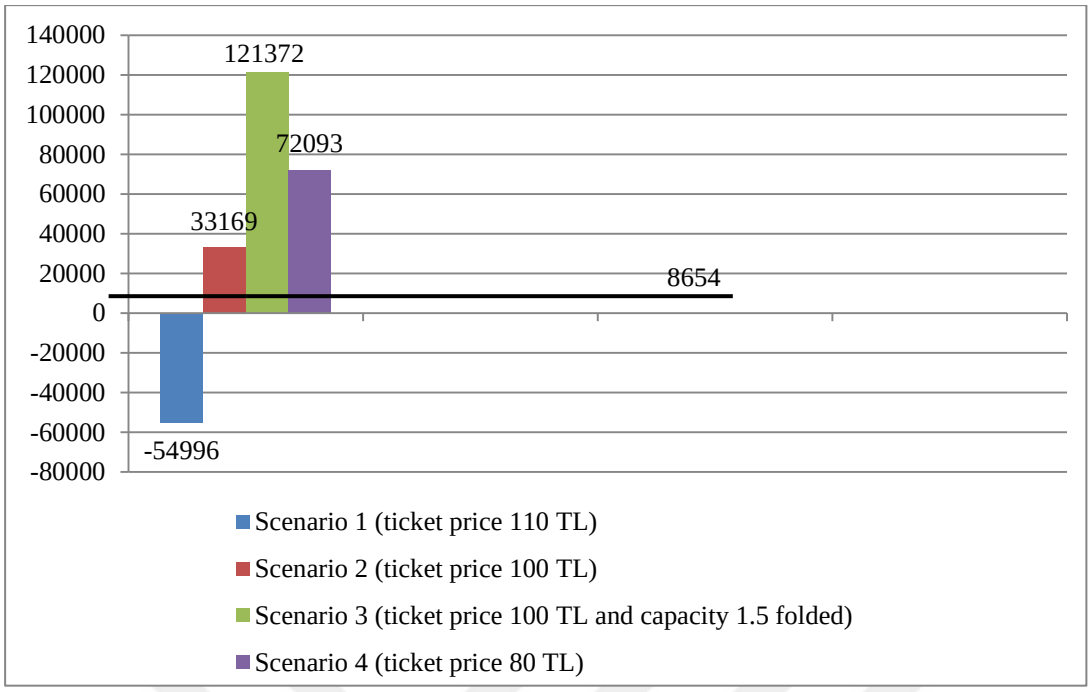

Figure 4.4 : Net weekly profit/loss of PTSO 3-1 in different scenarios in TL.

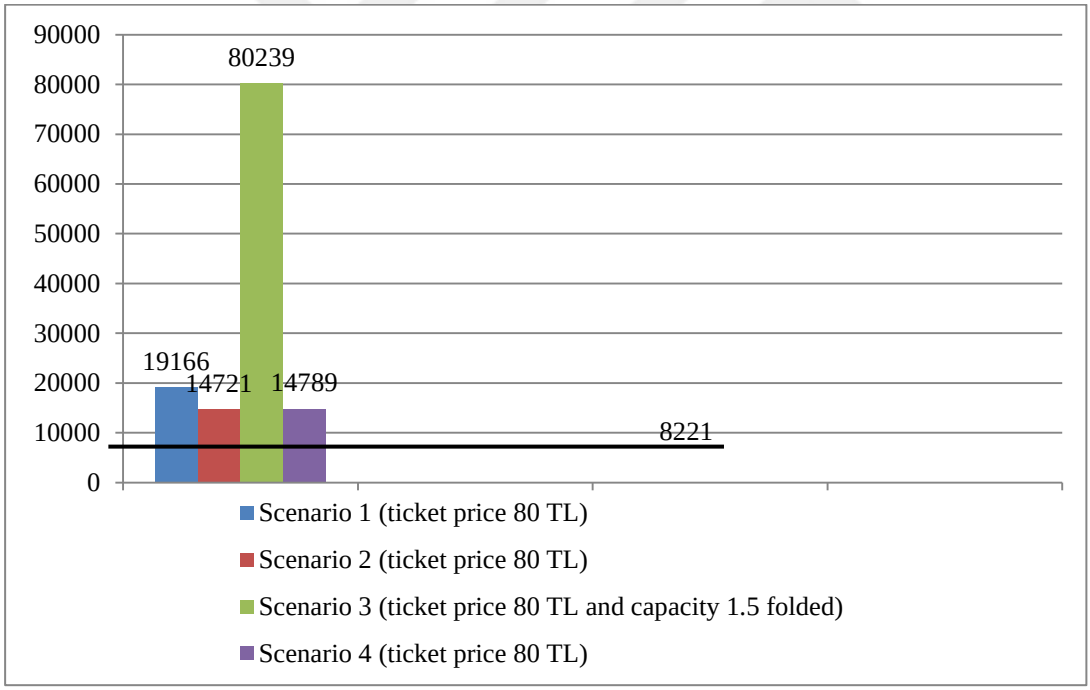

Figure 4.5 : Net weekly profit/loss of PTSO 4 in different scenarios in TL.

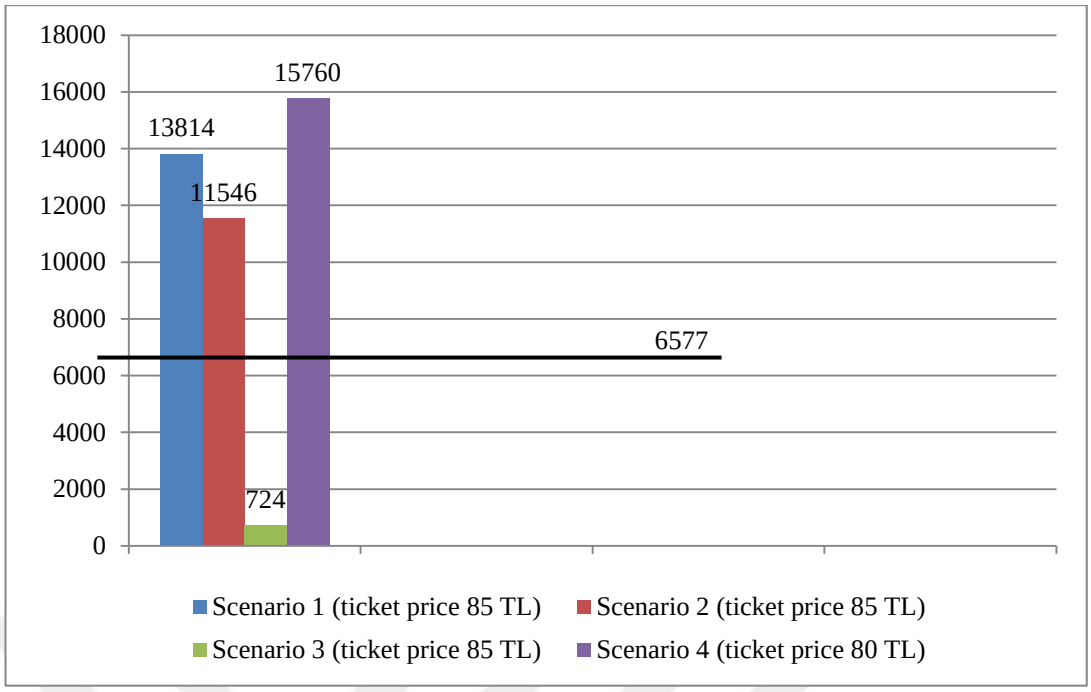

Figure 4.6 : Net weekly profit/loss of PTSO 5 in different scenarios in TL.

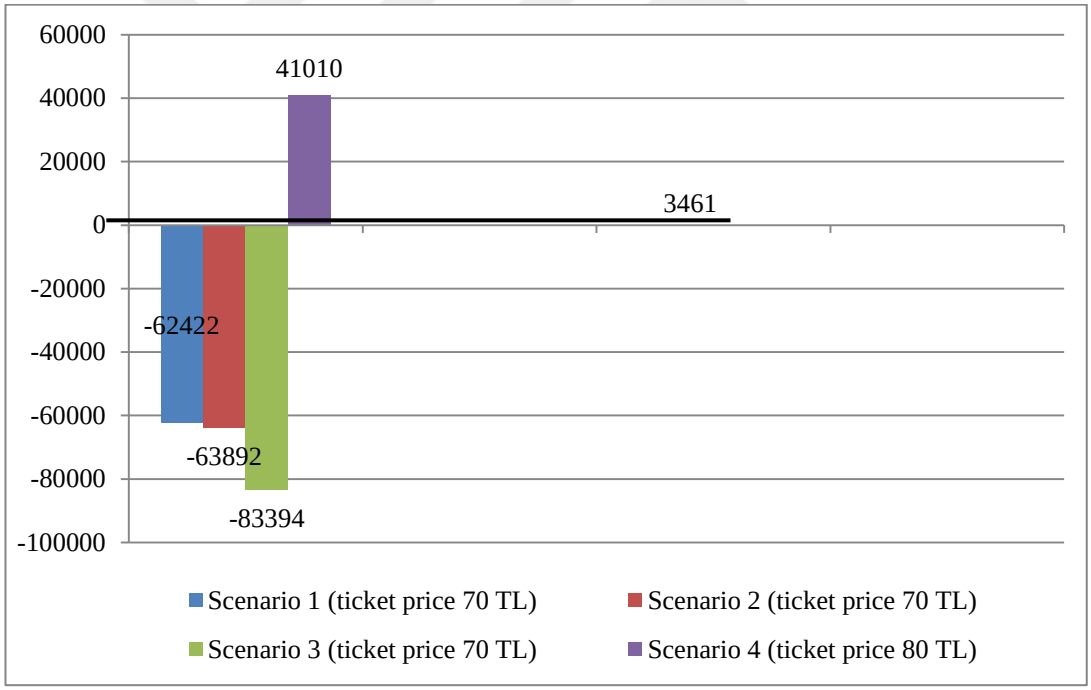

Figure 4.7 : Net weekly profit/loss of PTSO 6 in different scenarios in TL.

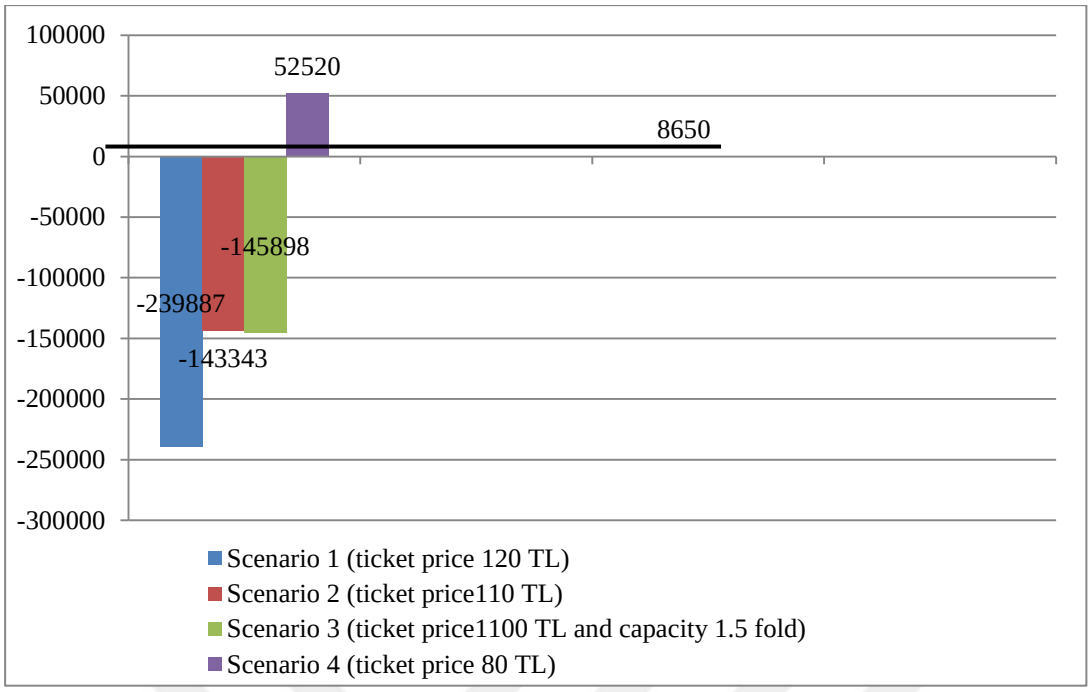

Figure 4.8 : Net weekly profit/loss of PTSO 1-2 in different scenarios in TL.

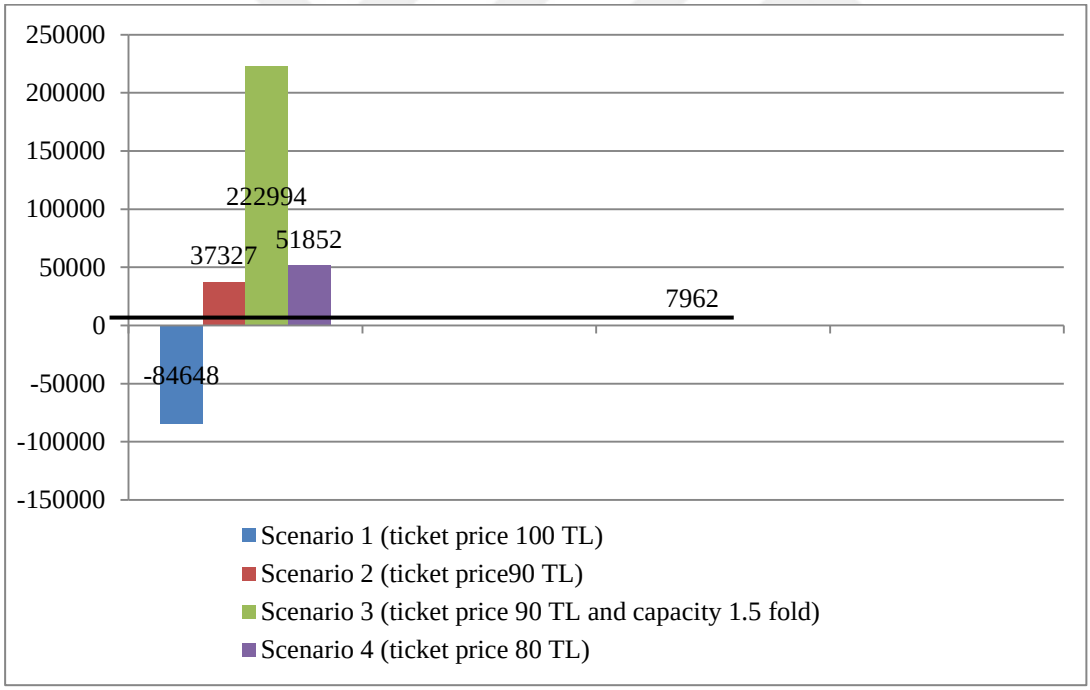

Figure 4.9 : Net weekly profit/loss of PTSO 2-2 in different scenarios in TL.

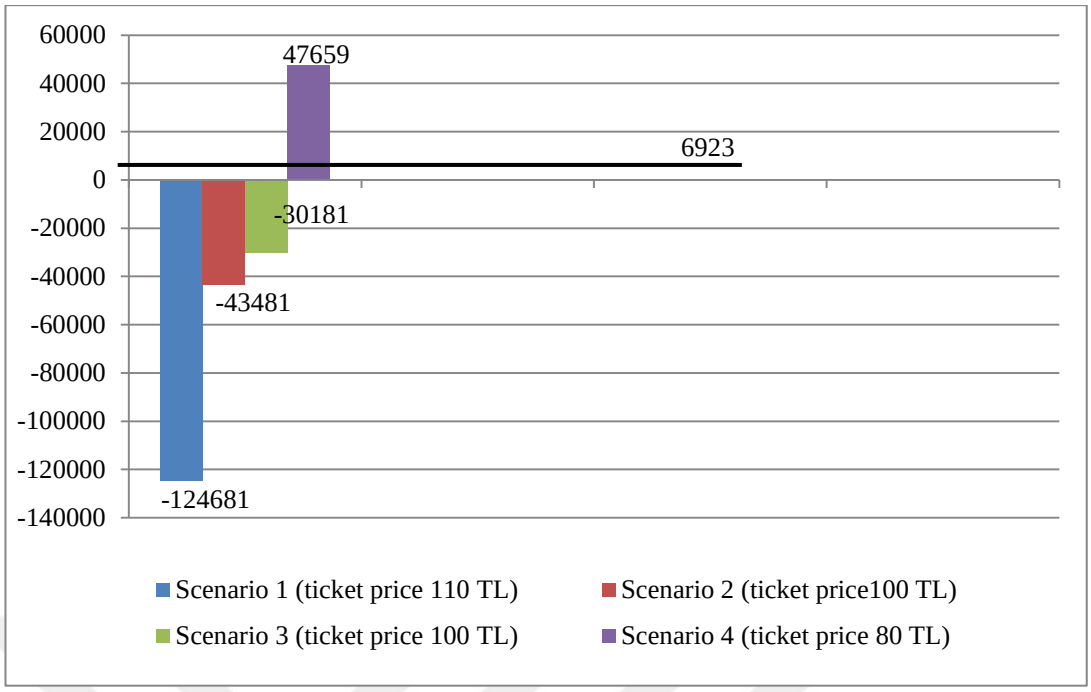

Figure 4.10 : Net weekly profit/loss of PTSO 3-2 in different scenarios in TL.

5. CONCLUDING REMARKS AND RECOMMENDATIONS

Commencing from mid-18th century in Britain and spreading to the other countries, there was a change of economy from the handicraft and agrarian to the machine-manufacturing and industry where it is called "Industrial Revolution" in the modern history. The icon of this revolution was steam engine where the locomotives driven by the steam power were of primary importance and incarnation of the rising trend. Booming in the early 19th century, union of the iron rails and steam produced a new means of transport, railways, which was supposed to create serious impacts on industry and social life. Henceforth, massive industrial outputs of Britain shall be transported to the other parts of the world and every passing day, new tracks were being constructed mostly by Britain and other superpowers to expand their economic, military and political purposes all around the world. From a social perspective, suburbs turned out to form a new generation of white collar workers and even rural and suburban life style was highly affected by this invention. However, railways paved the way for the continuity and progression of the industrial revolution. In the upcoming years and century, the rail industry became more powerful by introduction of the diesel and electric power. However, most worldwide railways were controlled by monopolies and the Post-Second-World-War era halted the incessantly-growing trend of the railways. From those days on, railways experienced an unproductive period and highways began to keep the place for the railways. Towards the last decades of the 20th century, a number of efforts were made to revive the rail industry and introduction of the high-speed railways and new technologies remarkably triggered the revival process particularly in Western-European countries and the Far-East. Turkey experienced a four-stage continuum in its history of railways. During the Ottoman Empire age, most of the railways were constructed by the British, French and German finance and involvement. Undoubtedly, these superpowers were mostly pursuing their own goals rather than the national interests of the locals. In opposition, Ottoman authorities were also trying to follow their domestic and national goals by expanding the rail lines within

its borders. However, those efforts failed to satisfy with regard to the conditions of that age. After the proclamation of the republic, new authorities accelerated the construction of Turkish railways in parallel with the national interests. However, in the third stage and as was the trend worldwide, railways in Turkey faced a depreciation after the World War II. This continued almost to the end of the century where in the early years of the 21st century, the government decided to cherish the transportation in the country and the rail sector was supposed to receive its share by introduction and expansion of the high-speed railways.

Construction of the railways requires a significant investment and financing such projects is a matter of paramount importance. Most railways in almost all countries around the world were projected, constructed, operated and maintained by the governmental monopolies. In the process of time, this approach posed serious problems related to the monopolistic bottlenecks and highly affected the efficiency of the railways. On the other hand, economic crises act as barriers in provision of public infrastructures such as railways and many governments are incapable of developing such infrastructures due to the budgetary limitations. These parameters, made many governments to look for financing alternatives and also efficiency revival in the rail sector. Starting from this point of view, participation of the private sector's financial, technical and managerial power was discussed under the framework of PPP approaches.

In fact, PPP is not a newly-discovered method and its early applications date back to the centuries and even millenniums ago. However, its extensive applications in both developing and developed countries might be regarded as a new trend. Early PPP rail projects were presented in Europe and then extended to the other parts of the world. However, transport sector was not the only one to be boosted by PPP approaches and other sectors such as energy, healthcare, telecommunications and etc. tried to take the advantages of this approach. There are hundreds of reports and academic studies both in favor of and in opposition to the success of such projects. In general, it is observed that the concept of value for money (VFM) is of the essence for the realization of a successful PPP infrastructure project and the process may turn out to be a long-term nightmare if the entire process and VFM is not analyzed in a hypercorrect manner.

European Union led a comprehensive process of liberalization and privatization in the rail sector and tried to boost competition in the European rail network by

formation of open-access railways. Degree of liberalization differs in EU members and they follow different approaches. Since early 1990s, the authorities enacted several directives to reach an inclusive and successful process of rail liberalization in Europe. Some observations show the efficiency of such efforts in some parts of EU railways while some economists criticize the overall success of the process.

In this study, we tried to propose a realistic and comprehensive analysis and model for the liberalization of TCDD. In an open-access rail market there are three major interest groups. In Turkey, these groups might be considered as the TCDD as the IP, private train-operating firms and passengers as service customers. With a holistic approach, it is possible and logical to claim that these interest groups follow diametrically opposite and conflicting goals. Passengers tend to have access to the budget and high-quality services during their time preferences. Private operators aim at keeping the ticket prices at their highest possible level and pay the lowest possible track access charge (TAC) to the infrastructure provider (IP). In contrast, IP aspires to collect higher amounts of TAC from private operators. IP is also responsible of the provision of a rail network which is accessible and acceptable by all layers of the society. As is seen, the objectives of the different interest groups are in sharp conflict. Utilization of the conventional optimization methods for modeling the behaviors and decisions to be made by the decision-makers may misdirect policy-makers since these methods tend to optimize the problem in a system-wide approach which is unrealistic. At this point, "game theory" can put forward its power in provision of a more realistic modeling of the liberalization process of the railways. The trump card for the game theory is its individualistic approach where all players follow primarily their own objectives without regard to those of the others. Besides, rail PPPs and market opening include a long period of a contract with a dynamic nature which is in absolute compatibility with game theoretic methods. Last but not least, game theory is capable of reflecting many engineering, socio-economic and political aspects of the problem in absence of the concrete data and quantitative information using ordinal payoff methods.

Within this context, I introduced three important 2×2 games including "Prisoner Dilemma", "Chicken" and "Stag-Hunt" with their pure mathematical explanations and applications in practical PPP rail projects. Afterwards, we applied dynamic entity of the game theoretic concepts to a long-term contract in which two private operators

are responsible for both operating the services and maintaining the track. It was shown that the game may face radical changes in various periods of the contract and lack of foresight and inclusion of penalties for delinquent side may threaten the overall success of the deal.

Hereinabove, we mentioned three interest groups in a liberalized rail market. To model the entire process and provide effective alternatives for policy-analyzers we developed a game theoretic simulating model using "GoLang" programming language. Although three interest groups follow conflicting points, they cannot act independently since the system simultaneously requires all three players. It is impossible to imagine a successful open-access rail market in absence of any of the mentioned groups. Consequently, the nature of the game in our sample is not zero-sum and the involved players have to cooperate to a certain extent. This necessitates the application of the "cooperative game theory". On the other hand, the payoffs (utilities) are not transferable and with this in mind, we developed and proposed a simulation using the concept of NTU cooperative (coalitional) game. To solve the bargaining problem, we examined a method similar to that of Nash solution with a difference in which we considered a feasible solution zone rather than a single solution to the problem. We applied the simulation to the Istanbul-Ankara high-speed railway and collected required data by conducting a stated preference (SP) survey in Pendik station in Istanbul. In our model, we included 6 private train Service operators (PTSO) with 9 services daylong, an infrastructure provider, TCDD, and 38243 passengers wishing to travel from the first station (Istanbul) to the other 5 stations ending at Ankara. However, due to the simplicity and negligible portion of the unboarding in way stations (Gebze, Izmit, and Eskisehir) these are excluded from the simulation.

The approach proposed in this thesis not only presents strategies to improve the liberalized rail network by providing better timetable for the services, but also provides the IP with higher compensation rates by collecting higher TAC amounts where resource allocation is optimized.

As for the future developments, we believe that the results of our simulator might be enhanced by application of reinforcement learning (RL). In this manner, the PTSOs and IP learn from each iteration of the negotiations and the best solution(s) might be

provided by the RL. It would be interesting to make a comparison between the results and refinements of this study with those obtained by RL techniques.

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APPENDICES

APPENDIX A: Questionnaire
APPENDIX B: Data extraction
APPENDIX C: Extraction of α and β values

APPENDIX A

1. Gender: Female ☐ Male ☐ 2. Age: 3. Profession:

4. Education: 5. Residence district: 6. Household population:

7.Ailedeki Özel araç Sayısı: 8.Kendisinin özel aracı ile yolculuk etme imkanı var mı?

9. Household income (TRY): <1500 ☐ 1500-2500 ☐ 2500-3500 ☐ 3500-4500 ☐ 4500-5500 ☐ 5500-6500 ☐ 6500-7500 ☐ 7500-8500 ☐ 8500-10000 ☐ >10000 ☐

10. Kendisinin aylık geliri (TL): <1500 ☐ 1500-2500 ☐ 2500-3500 ☐ 3500-4500 ☐ 4500-5500 ☐ 5500-6500 ☐ 6500-7500 ☐ 7500-8500 ☐ 8500-10000 ☐ >10000 ☐

11. Means of transport used to arrive at the HSR station in Pendik, Istanbul:

12. Destination: 13. Travel purpose: 14.Paid ticket price:

15. How often do you use this train?

16. Do you generally use this train during week days or on weekends? :

17.Which time span is more preferred for you in the daily schedule?

6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
☐	☐	☐	☐	☐	☐	☐	☐	☐

18. Assign a value for travel time importance and accuracy (departure/arrival) in the range of 1 (not that important) to 10 (absolutely important).
19. Assign a value of 1-10 for the importance of the ticket price in your preference criteria.

A İstanbul- Ankara Yeni YHT Treni Süre: 2 saat Ücret 250 TL	B İstanbul- Ankara Yeni YHT Treni Süre 2.5 saat Ücret 150 TL	C İstanbul- Ankara Normal Tren Süre 3 saat Ücret 130 TL	D Hiçbirini tercih etmem
A İstanbul- Ankara Süre: 3 saat Yeni YHT Treni Ücret: 110 TL	B İstanbul- Ankara Süre: 3.5 saat Normal Tren Ücret: 80 TL	C İstanbul- Ankara Süre: 4 saat Normal Tren Ücret: 70 TL	D Hiçbirini tercih etmem
A İstanbu - Ankara Süre: 4 saat Yeni YHT Treni Ücret: 60 TL	B İstanbul- Ankara Süre: 5 saat Normal Tren Ücret: 40 TL	C İstanbul- Ankara Süre: 6 saat Normal Tren Ücret: 30 TL	D Hiçbirini tercih etmem
A İstanbul- Ankara Süre: 3.5 saat Yeni YHT Treni Ücret: 100 TL	B İstanbul-Ankara Süre: 4 saat Yeni YHT Treni Ücret: 80 TL	C İstanbul- Ankara Süre: 4.5 saat Normal Tren Ücret: 70 TL	D Hiçbirini tercih etmem

APPENDIX B

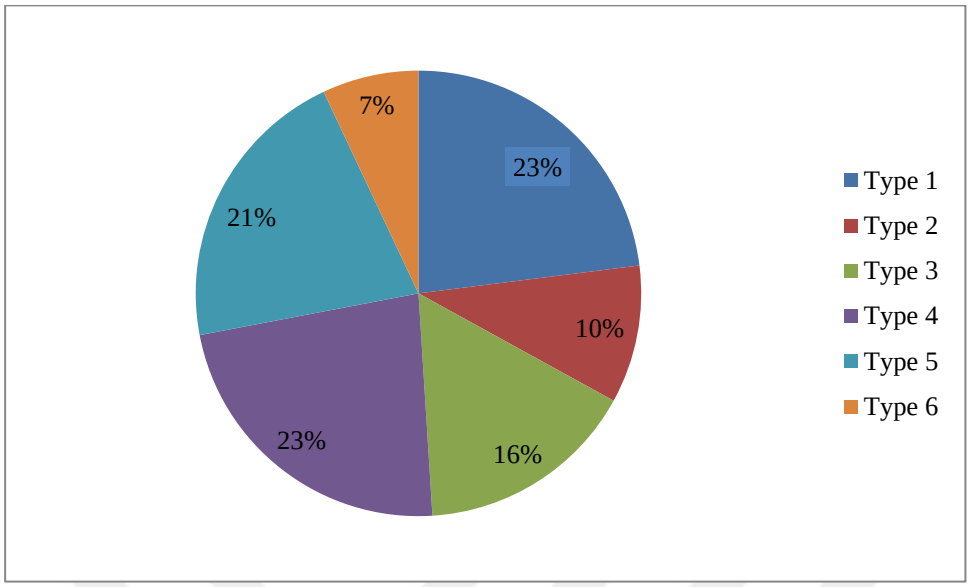

Figure B.1: Percentage of passenger types in the conducted survey.

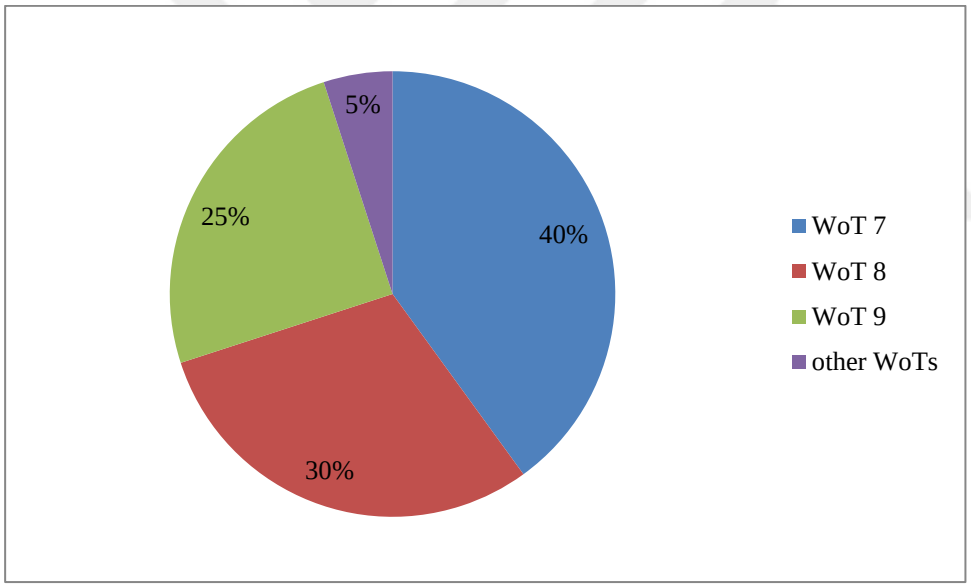

Figure B.2: Percentage of passengers type 1 with different WoTs.

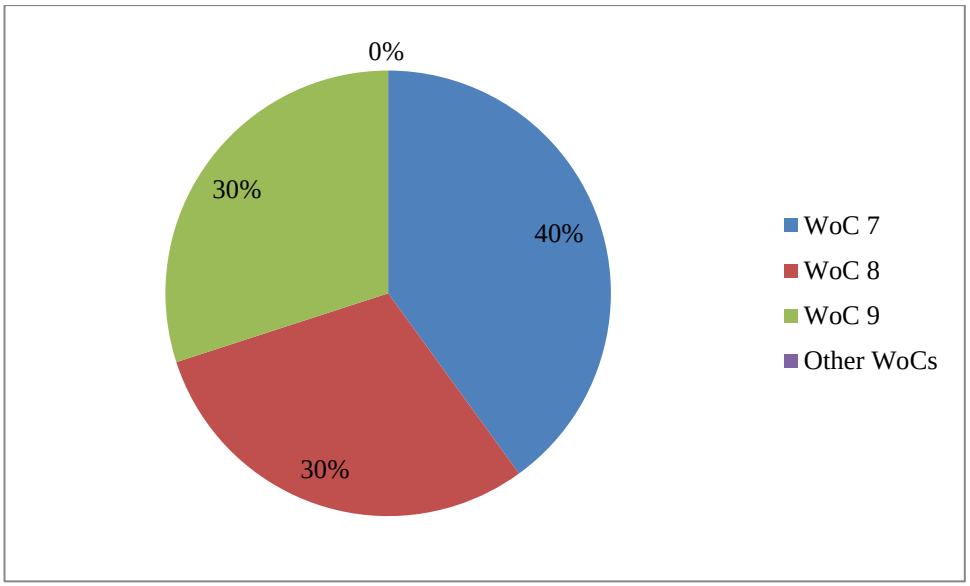

Figure B.3: Percentage of passengers type 1 with different WoCs.

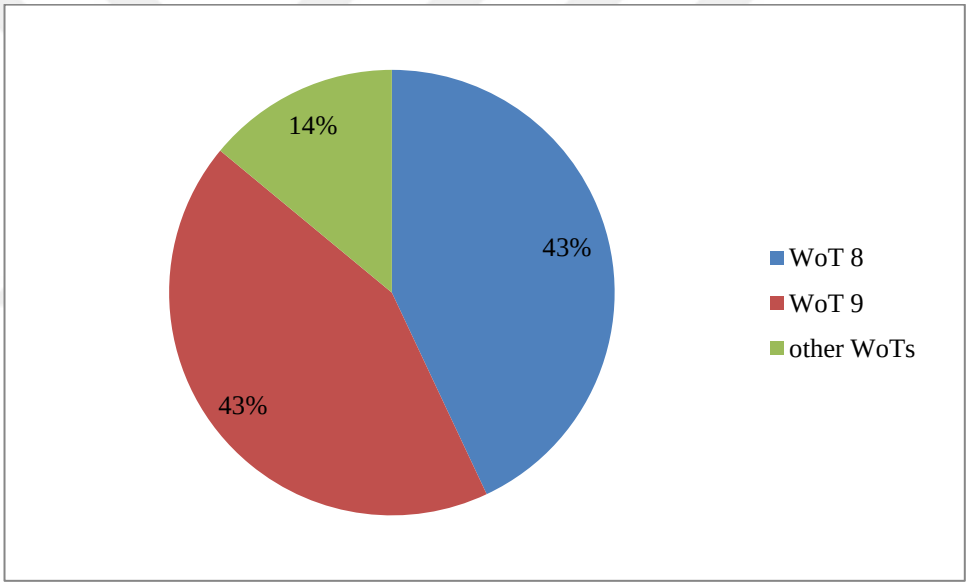

Figure B.4: Percentage of passengers type 2 with different WoTs.

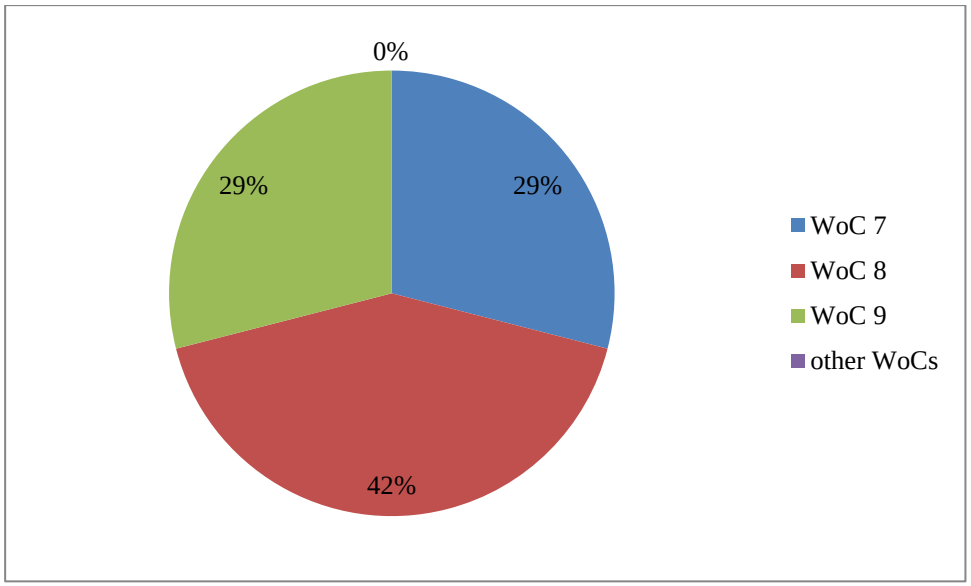

Figure B.5: Percentage of passengers type 2 with different WoCs.

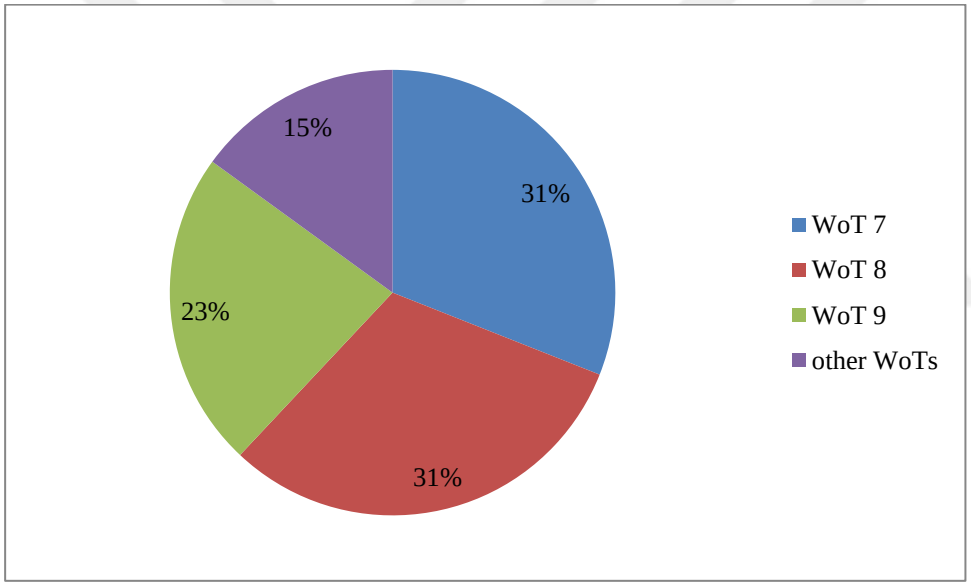

Figure B.6: Percentage of passengers type 3 with different WoTs.

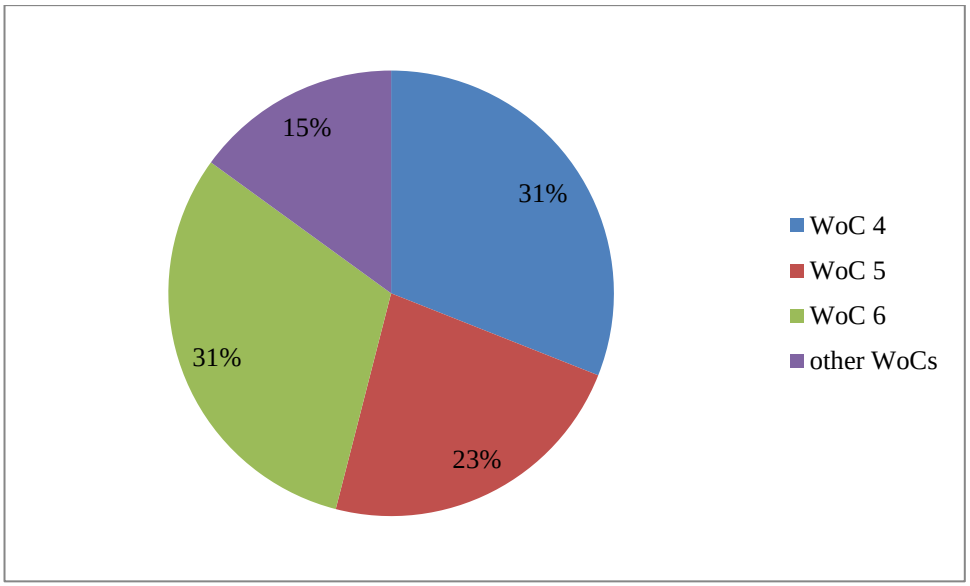

Figure B.7: Percentage of passengers type 3 with different WoCs.

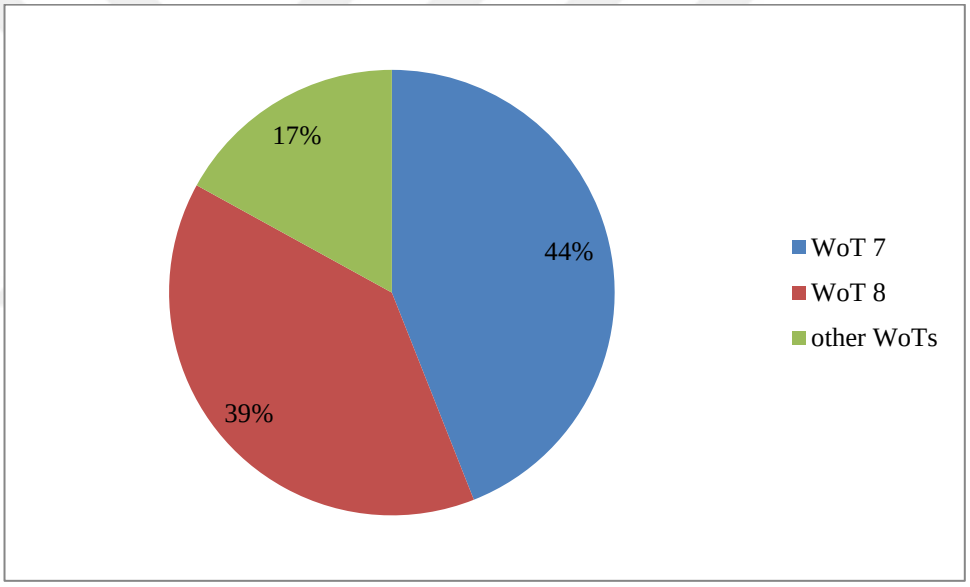

Figure B.8: Percentage of passengers type 4 with different WoTs.

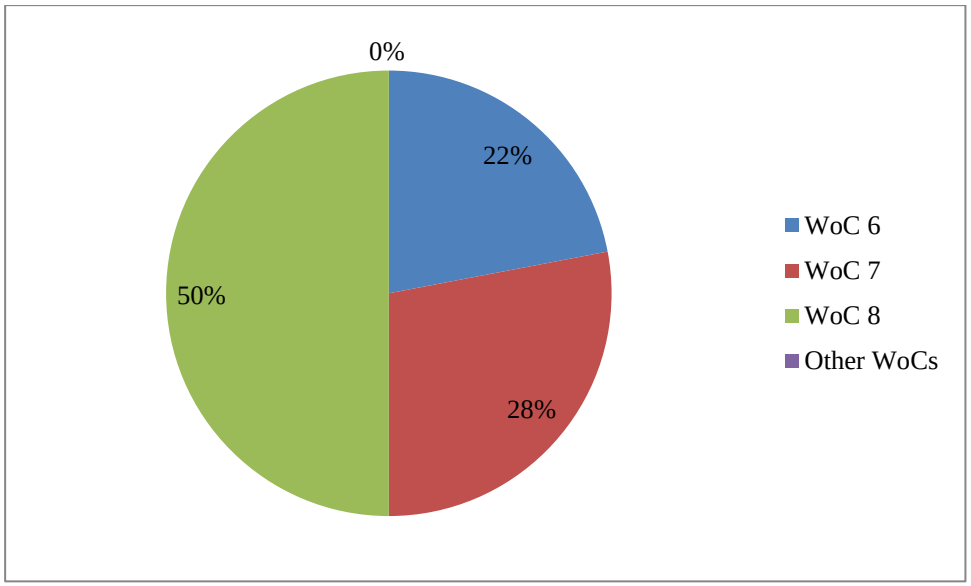

Figure B.9: Percentage of passengers type 4 with different WoCs.

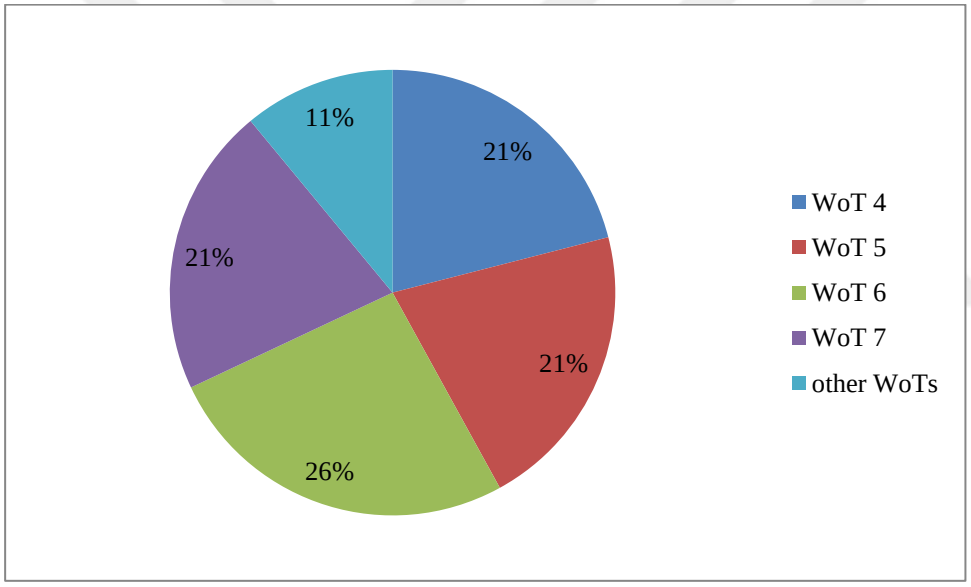

Figure B.10: Percentage of passengers type 5 with different WoTs.

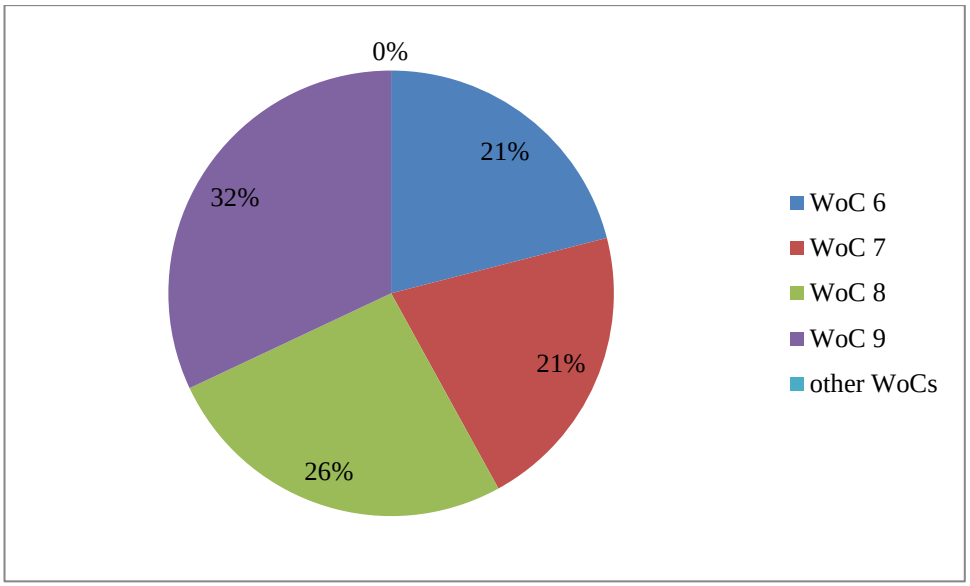

Figure B.11: Percentage of passengers type 5 with different WoCs.

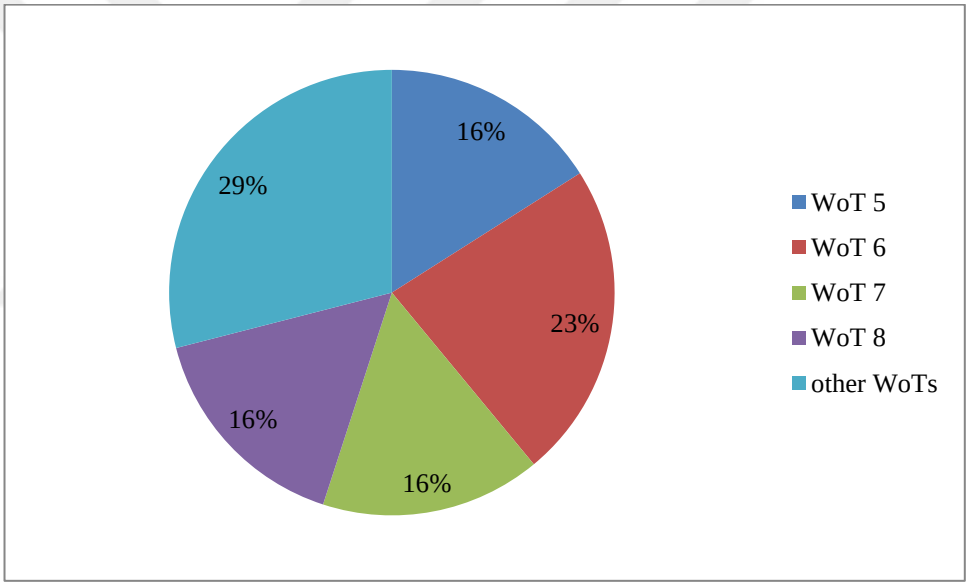

Figure B.12: Percentage of passengers type 6 with different WoTs,

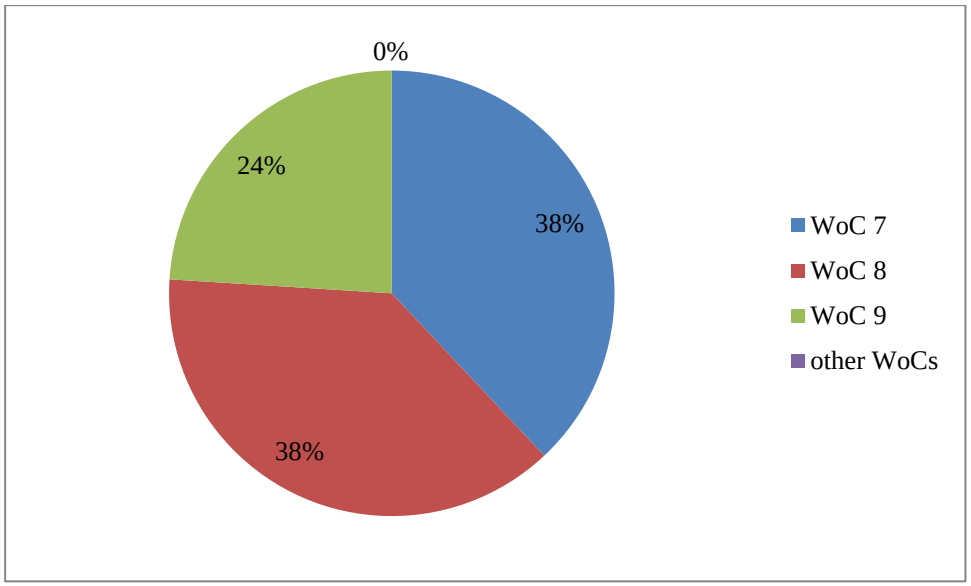

Figure B.13: Percentage of passengers type 6 with different WoCs.

APPENDIX C

Table C.1 : Extraction of β for passengers with WoC of 9.

Ticket price	Mean value	Rounded to
≤70	1	1
70<Pt ≤75	0.92	0.9
75<Pt ≤80	0.86	0.85
80<Pt ≤85	0.80	0.8

Table C.2 : Extraction of β for passengers with WoC of 6.

Ticket price	Mean value	Rounded to
≤70	1	1
70<Pt ≤75	1	1
75<Pt ≤80	0.98	1
80<Pt ≤85	0.97	0.95
85<Pt ≤90	0.91	0.9
90<Pt ≤95	0.86	0.85
95<Pt ≤100	0.81	0.8
100<Pt ≤105	0.77	0.75

Table C.3 : Extraction of α for passengers with WoT of 6.

Ticket price	Mean value	Rounded to
$5<t_v \leq 15$	1	1
15<tv≤30	0.96	0.95
30<tv≤45	0.89	0.90
45<tv≤60	0.85	0.85
60<tv≤75	0.79	0.80
75<tv≤90	0.73	0.75

Table C.4 : Extraction of α for passengers with WoT of 9.

Ticket price	Mean value	Rounded to
$5<t_v \leq 15$	0.83	0.85
15<tv≤30	0.77	0.75

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PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

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