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Anantharaman, Senthil Kumar

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# Essays on Modelling Public-Private-Partnerships (PPP) for Indian Emergency Medical Services

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Fellow Programme in Management

Indian Institute of Management Indore, Rau-Pithampur Road, Indore

M.P, India- 453556.

By

Senthil Kumar Anantharaman

Date: 28 December 2021

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"***Meaning without a purpose is meaningless"***

## ABSTRACT

Medical emergencies occur anywhere, at any time, in any country irrespective of whether it is a developed, developing or an underdeveloped country. These emergencies occur by the hour, consuming a lot of resources and sometimes, without even achieving the desired results, i.e., to save lives. Medical emergencies have been around since the start of the human civilization, however, they gained recognition as a specialty only around 30 years ago (Chung, 2001). An emergency medical system's goal should be to provide universal and integrative emergency care right from the time it receives information from an emergency user (Dykstra, E. H, 1997). Further, in a country like India, the seventh largest country, and with the second highest population in the world (David, S. S., & Vasnaik, M, 2007) and high income disparity, the implementation and context of the emergency medical system should be in a way to increase health equity and not worsen the current health disparities (David, S. S., & Vasnaik, M, 2007). This challenge faced by India and similar developing nations can be attended to by promoting systematic development of an evidence-based emergency medical system that is more cost-effective than those in developed countries like the USA, Canada and certain European countries where there is lesser income disparity. To design an effective emergency medical system, there is need to address questions such as how it would integrate with the current health-care infrastructure, local communities as well as their values, and the financial resources that would be needed to augment the services step by step (Gupta, M. Das, & Rani, M. 2004). In India, the public sector accounts for less than 20 percent of the total healthcare expenditure, which is the lowest in the world, and is less than 1% of the country's GDP (KPMG, 2005). Around 94% of the amount of private expenditure is from out of the pockets of citizens, and the remaining 6% is the provision's expenditure (Development Bank A, 2015). The way forward for the government to address this challenging situation is to consider the Public-Private Partnerships (PPP) model in the emergency healthcare sector in India. The emergence

of PPP in India has provided a viable solution wherein the government-led public sector forms a synergetic partnership with the technically advanced and innovative private sector (Raman, A.V et al., 2008). In emergency medical services, the government set-up 108 partnerships in 2005 (Besley, T., & Ghatak, M. 2017) with private organizations, such as GVK, Ziqitza Health Care Ltd., to deal with fatal emergencies, for example, dealing with the medical emergency during the Fani cyclone[1] at Odisha in 2019. However, the emergency services are fragmented in India (Subhan, I., & Jain, A. 2010), with many private services having entered the arena without regulation. Though this may look to be a good social and altruistic sign, in the long-run, it would hamper the progress of emergency services across the country. These questions will be well-addressed in this study when the rationality of promoting the emergency service systems is evaluated from the financing point of view. Further, in this study, we model the PPP contracts in accordance with the government's plan to integrate emergency services inclusive of fire and police with emergency health services under a common emergency telephone number, 112. Evidence is available to show that several roles, strategies, rules, and pay-offs govern procedures in the partnerships between the public sector and private firms (Bettignies, J.-E. de, & Ross, T. W, 2004). Thus, modeling them as complex games can help to better understand the failures and difficulties in such partnerships (Scharle, 2002). In this context, the researchers are implementing Nash bargain solutions in their research works to understand financial renegotiations (De Brux, J. 2010). However, there are very few studies to understand why financial renegotiation between government and service provider fails in a PPP contract. Through this study, we hope to provide a solid foundation to the integrated emergency medical services, which in turn, would provide Indian citizens the same equity, access, and quality of services which have been enjoyed by the people in the developing countries for decades.

[1] Fani cyclone hit many parts of Odisha in April- May of 2019, article by Vishwa Mohan (May 4, 2019), Times of India.

In the first essay, we have modeled funding mechanisms for Profit-based (Corporate) service providers to provide emergency medical services in PPP during natural disasters such as cyclones and tsunamis or pandemic-like situations such as Covid-19 when there is an unprecedented increase in demand of this service provision. In the second situation, that is, pandemic-like situations, we have considered modeling conditions when the service provider is successful in renegotiating with the government as well as when renegotiation is unsuccessful and investor goes ahead with the funding under government intervention.. Insights from the study indicate that government underinvests during regular situations, whereas during situations which require unprecedented rise in demand, it needs to monitor the service providers to prevent moral hazards.

In the second essay, we have modeled funding mechanisms for non-profit-based (NGO) service providers under similar conditions as in the first essay. Further, in case of an unprecedented rise of demand, we have restricted to modeling in renegotiation, as the case of renegotiation failure does not occur in case of non-profit-based service providers. Insights from the study show that the government has preference for investing in non-profit service providers as their pay-off increases with the payoff of the non-profit service provider (SP).

In the final essay, we have modeled advertising as a signal to convey the type of service provider (profit/non-profit) to the citizens (/Users/Patients); and also help the service providers decide their service provision. The study reveals that in regular situations, the advertisement strategy may aid to serve the patients when they require the emergency services. Further, the government may prefer either of the SPs (Profit-Oriented or Non-Profit-Oriented) to provide better payoffs in the PPP contractual relationship.

We find that the government needs to incentivize service providers to attain demand /service realization. Alternatively, it can penalize service providers by formulating policies if the effort

decreases with an increase in investment, as in few scenarios. Further, in all scenarios the government needs to formulate policies that aid investment in insurance companies so that citizens have to make less “out of pockets payments” that are quite expensive in emerging economies like India. Though insurance schemes have been launched by the central government in the past few years, various states that have been in PPP -based contracts for emergency health services need to coordinate with the centre to launch more innovative insurance schemes to reduce “out of pocket" expenses” thereby, improving citizen’s welfare.

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## 1. INTRODUCTION

Medical emergencies occur anywhere, at any time, in any country irrespective of whether it is a developed, developing or an underdeveloped country. These emergencies occur by the hour, consuming a lot of resources and sometimes, without even achieving the desired results, i.e., to save lives. Medical emergencies have been around since the start of the human civilization, however, they gained recognition as a specialty only around 30 years ago (Chung, 2001). An emergency medical system's goal should be to provide universal and integrative emergency care right from the time it receives information from an emergency user. Further, in a country like India, which is the second most populous country in the world with high-income disparity, the implementation and context of the emergency medical system should, in every way, try to increase health equity and not worsen current health disparities. This challenge faced by India and developing countries like India can be attended to by promoting systematic development of an evidence-based emergency medical system that would be more cost-effective than the ones in developed countries like the USA, Canada and certain European countries where there is lesser income disparity. To design an effective emergency medical system, there is need to address questions such as how it would integrate with the current health-care infrastructure, local communities as well as their values, and the financial resources that would be needed to augment the services step by step. These questions are well addressed when the rationality of promoting emergency service systems is evaluated from the financing point of view. Further, deficiencies in healthcare can be overcome only by reform. The emergence of Public Private Partnerships (PPP) in India has provided a viable solution. In this model, the government-led public sector forms a synergetic partnership with the technically advanced and innovative private sector. The government set up 108 partnerships in 2005 with private organizations, such as GVK and Ziqitza

Health Care Ltd., to deal with fatal medical emergencies to diminish the number of lives lost, for instance, as in the case of the Fani cyclone, which caused havoc in Odisha in 2019. However, the emergency services are fragmented in India, with many private services coming into play without regulation. Though this may be interpreted as a good social and altruistic sign, in the long run, it could hamper the progress of emergency services across the country. In this study, we propose a model, as shown in the below tree for funding of PPP contracts which the government can use in its plan to integrate all emergency services including fire, police with emergency health services under a common number, 112 which due to systemic issues during COVID-19 leads to scenarios that involved both profit and non-profit emergency providing bidders renegotiate with government or bargain with investor between the investor.

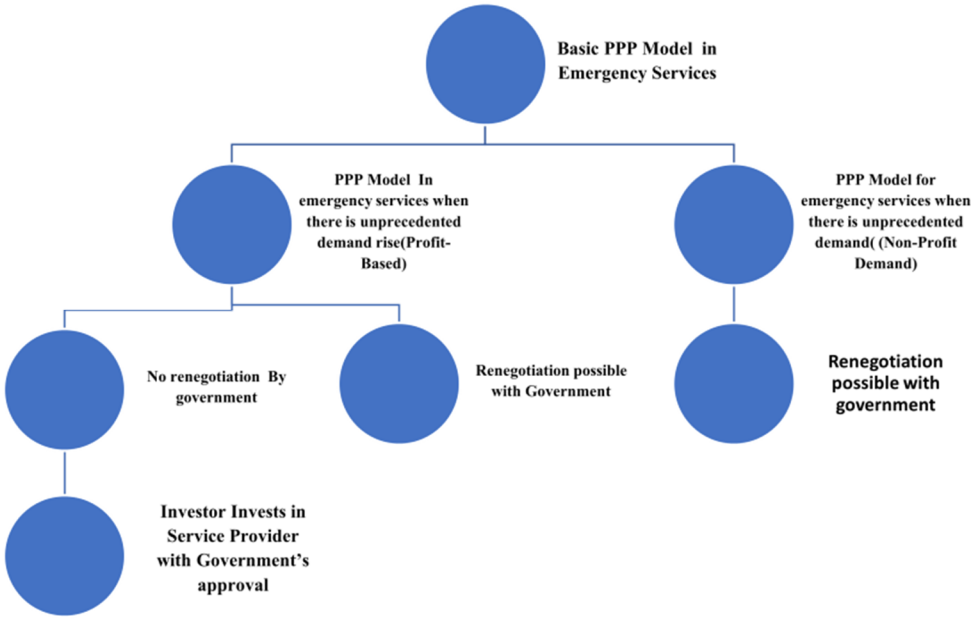


**Figure 1: The Tree Model to Overcome Emergency Service PPP Systemic Issues**

Through this study, we hope to provide a solid foundation to the integrated emergency medical services, thereby providing citizens of India equity, access, and quality of services, in line with those enjoyed by the citizens of the developed countries.

# 2 PROBLEM CONTEXT

## 2.1 Emergency Medical Services

The emergence of emergency medical services can be traced to the time when carts were used as ambulance services in transporting patients. Advances in technology and industry led to the emergence of self- powered ambulances, whose design later underwent major changes in the 1970s (Chung, 2001) Further advances in communications technology provided the much-needed support required in the ambulance services. The government used these emerging technologies to launch the 9-1-1 system /1-1-2 systems, the nationwide emergency services hotline. The number to get medical help is the same throughout the country. In 1966, the emergency departments collaborated with the department of transportation to integrate the crisis hotline with emergency communication systems to provide EMS support, with a special focus on heart attacks and trauma (Dykstra, 1997). The 911 process, for example, in Canada is a thorough process which can send aid as quickly as possible to save lives. As soon as a 911 call is received by an EMS operator, a trigger known as Canadian Triage Acuity Scale (CTAS) is used to prioritize patients and dispatch timely and appropriate help.

## 2.2 Issues faced in managing Indian EMS

While developed countries such as the USA, European countries, Canada and Australia have developed international emergency medicine, there is absence of a structured EMS in India (Subhan & Jain, 2010). Even though a centralized accident and trauma services (CATS) ambulance service system was incorporated in the early ’80s this situation continued to exist until the late ’90s. This was mainly due to a number of factors such as the lack of recognition to emergency medicine by Medical Council of India (MCI), the absence of a common driving force i.e. an integrator, dearth of formal emergency departments, and lack of proper training (both at

Undergraduate (UG) and Post Graduate (PG) level). To overcome these challenges and as a first step, the first privatized emergency department was established by Sundaram Medical foundation in the late ‘80s, based on the American emergency systems. The EMS in India can currently be described as fragmented, with the most dominant model being that of the Emergency Management and Research Institute (EMRI) (David, Vasnaik, & TV, 2007), which is managed by GVK, an Indian conglomerate. Most of the states have adopted the EMRI Medical services, using these services provided by GVK; however, some states use other agencies to operate the EMRI structure. EMRI is a 108-ambulance service that operates on public-private partnership (PPP) agreement between the various state governments and GVK EMRI. Another important scheme is the one launched in 2006 (David, Vasnaik, & TV, 2007) by Madhya Pradesh’s department of health and family welfare by the name of Janani Express scheme, which was again a Public-Private-Partnership (PPP) model focusing on safe ambulance transportation. Other Non-Governmental Organizations (NGOs) and institutes like National Network of Emergency services (NNES), Life Support Ambulance Service (LSAS), Ambulance service for all (AAA) and Indian Institute of Emergency Medical Services (IIEMS) have also played a key role in developing the EMS in India. Almost all states of India are operated by agencies which have central government support in the form of capital expenditures while the operating expenditures are borne by the agencies in different states. The EMS in India is similar to the western system of 911. It has an emergency number 102 for calling an ambulance, however, over a period of nearly two decades, it is observed that there is lack of uniform access number across entire India. Besides, there is also lack of awareness about the existing numbers, which are several in number and vary across states, making access to emergency help very difficult. Further, since EMS systems have been unaccountable, corrective measures have rarely been successful. However, in

2017, the political leadership and bureaucracy showed great will to initiate the process of allotting a unique emergency number, 112. However, the success of this new initiative will largely depend upon how the government (both center and states), Non-governmental Organizations (NGO's) and other private agencies across states integrate and provide a channel that is right in approach, and is efficient and effective to the use. However, despite all these measures, the EMS in India is far from satisfactory and is plagued with issues, some of which are summarized below.

- Non-uniformity of services across states. This may be due to the monopoly of emergency service providers in a state. It is seen that Maharashtra and Tamil-Nadu always perform better in terms of emergency health outcomes due to the competition that exists between various emergency service providers.

- Problem of identity that exists between regular health professionals and emergency health professionals. Besides, the salaries of EMS professionals are way below than regular health professionals, causing fragmentation of these services.

- Rural areas have particular difficulties in maintaining EMS, due to low call volumes, which in turn, lead to high cost per transport and insufficient resources to meet day to day operational requirements.

## 2.3 Motivation (Purpose) of Research

The purpose of this research is to provide a PPP-based contracting framework that would enable EMS in India to provide its citizens, services with

1. Equity
2. Quality
3. Access
4. Efficiency
5. Flexibility

Also, this study applies the methods of the game theory, like principal-agent methods, and signaling to model important elements that would aid the EMS consumers, government and service providers to:

a. Maximize Value for Money (VFM)

b. Maximize Social Welfare (Well-Being)

## 2.4 Scope

The scope of this work is limited to emergency medical services in the Indian context, though comparisons have been made with reference to Canadian Emergency medical services. Further, only PPP models of BOT/BOO/BOOT type has been considered in this work for both simplicity and a realistic portrayal of the situation. Finally, though there may be many other methods like empirical and qualitative approaches that can elucidate positive results which could benefit the current real situation of Indian EMS, we have tried to effectively use the game theory methods, such as the principal-agent method, and signaling to come up with optimal solutions that the Indian EMS can use to improve its services.

## 2.5 Organization of the Thesis

The thesis is organized in the following way. The initial chapters introduce the readers to the research context of this work, which is emergency medical services in India, the motivation/purpose and scope of the study. The next section discusses the need for innovative funding mechanisms for emergency medical services in India. The subsequent section provides the literature review on emergency medical services, public-private-partnerships (PPP) and the different modeling approaches used in research. This is followed by the first essay on modeling funding mechanisms for different scenarios and situations for profit-based service providers. The second essay focuses on modeling funding mechanisms for non-profit-based service providers. This is followed by the third essay, which discusses how advertising signals the type of service provider to the citizens (Users of emergency medical services). No advertising strategy can positively impact patient's decision to accept or reject the services provided by the Service Provider, provided that the Service provider does not reveal its type to the patients. The final section includes discussions on the model results, management contributions, and significance, followed by conclusions and a comprehensive reference list and appendices.

# 3 REALIZATION

The evolution of the emergency medical services (EMS) system in India has been a slow process. The importance and need to integrate public health and emergency services like police and fire in the country gained pace since 2007. However, the need for EMS has gained major traction during this current period of COVID pandemic which has necessitated an overhaul of the EMS to deal with the rising number of patients infected by the virus. This realization has also led to a streamlining of the processes between the central and state governments, which had till now been functioning in silos, paving way for more effective services to the citizens.

This was mainly because the funding mechanisms in India, unlike the West which has more competitive funding. In India, funding is driven by the center. However, it was seen that the disbursement process to the state government was not streamlined, which severally impacted implementation of the EMS.

Further, service providers across that the country required an initial capital to provide EMS like ambulances, emergency rooms etc. This resulted in unhealthy competition among them. As a result, the EMS was severally impacted and could only offer limited support.

With India showing one the highest COVID cases in the world, it became necessary to create an effective integrated emergency health services system. However, to create one, the funding mechanisms need to be given a complete retrieval with focus on implementing public private partnership across the various states in synchronization with the center. This, then combined with suitable operational processes across the entire country would pave way for an effective yet accessible and equitable EMS capable to provide the citizens a much-needed public welfare that would stand the test of time.

# 4. LITERATURE REVIEW

## 4.1 Introduction and Organization of Literature Review

The literature is organized into three main sections, as given below in Figure 2.0.

1. Literature on Emergency Medical Services
2. Literature on PPP Contracts
3. Literature on the Modelling Approach

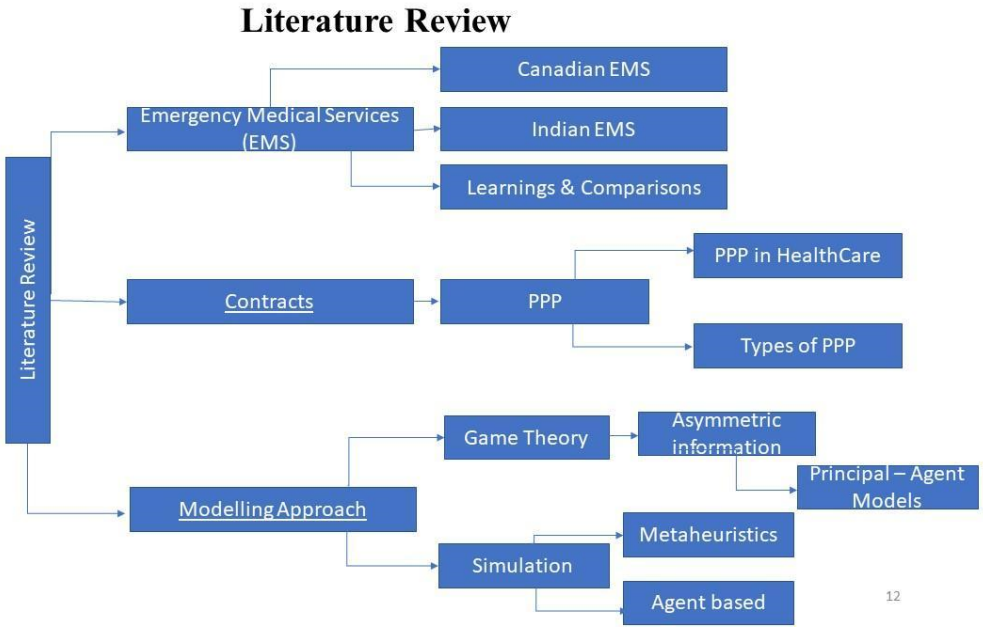


**Figure 2.0-Literature Review**

## 4.2 Emergency Medical services

Even though emergency medical services gained recognition around 30 years ago (Chung, 2001), it has been in practice for ages since the origins of human civilization. The most efficient EMS systems in the world fall into two broad categories (Dykstra, 1997), the Anglo- American model practiced in the USA, Canada, New Zealand, Australia and Sultanate of Oman; and the German-Franco model that is widely practiced in countries like France, Germany, the UK, and Austria..

In the Anglo-American EMS system, which is based on the philosophy of scoop and run, patients are brought as quickly as possible to the hospital's emergency care departments with experienced paramedic professionals having a medical oversight of the situation. These are essentially Basic Life Support (BLS) systems whose focus is to provide non-invasive basic care and rapidly transport patients to a medical facility. In the Franco-German model, which is based on the philosophy of field-treat and stabilize, physicians and emergency doctors treat the patients first at their homes, or at the scene of the emergency, based on their clinical expertise and then based on necessity, the patients are transported to the hospitals. These are Doctor-based Advanced Life support (Doc- ALS) systems which provide slightly sophisticated invasive therapy at the scene and during transport to hospitals. Both these systems have their advantages and drawbacks. Some developing countries such as India have adopted the Anglo-American model; though of late it is also trying to integrate both the systems to maximize the advantages while trying to address the drawbacks of these systems.

### 4.2.1 Comparing Indian EMS with a developed nation's EMS (Canadian EMS)

An estimate of economic benefits of emergency medical services related health activities measured in monetary units is in general synchronous with estimates of the costs, though it does not imply accepting a particular valuation mode. It has been observed by researchers that the waiting time in an emergency department at the receiving hospitals and the quality of care received by the patients were some of the factors that shaped the experience of an individual (Boudreaux & O'Hea, 2004) in an Emergency Room (ER) across various regions and provinces and territories of Canada. This, in turn, determined the effectiveness of the emergency medical services in Canada. One of the major findings that appear to have dominated in late 2010's (Holroyd, Rowe, & Sinclair, 2004) was those users of Emergency room (ER) were experiencing

negative feelings and serious strain in certain aspects of the Canadian health care system, specifically the lengthy waiting times and poor interaction of physicians with the patients. This clearly showed a lack of care by the Emergency departments. Research also revealed that ER patients in Canada were not given an estimate of waiting time, leading to their dissatisfaction with the service. Further, ER overcrowding had a destructive as well as a demoralizing impact on professionals and physician in hospitals, which led to poor physician-patient interaction. This implied that improvement in staffing could reduce the anxiety and tension among staff, especially physicians and professionals in emergency rooms. Currently, Ontario alone requires around 1500 emergency care physicians while it currently has 700 (McLay & Mayorga, 2010).

Further with a significant reduction in staff in ER rooms in the past years, addition of alternative service providers and specialty paramedic professionals needs to be considered. The integration of various healthcare service providers may alleviate the stress on the current ER system, thereby, improving the experiences of an ER patient specifically like care provided and better physician-patient interaction.

Further, the impact of the integration of new healthcare service providers may also improve the waiting times, leading to a positive experience for an emergency room patient (Taylor, 1976). It is also found that there a linear relationship exists between the acuity of a patient and their satisfaction (Hansagi, Carlsson, & Brismar, 1992). The patients who required immediate care were more satisfied than those who needed urgent care, and those who were treated for urgent care were better satisfied than those who needed non-urgent care. But it was also found that the actual throughput times were not nearly as strongly related to the overall satisfaction of the patients as the throughput times that were perceived in the ER systems. Therefore, ER needs to

improve patient satisfaction by managing their expectations across Canada on throughput times, and as well as reducing delays.

In contrast to Canada, previous research indicates that in India the awareness and knowledge of the existence of emergency services among the public is a deterrent in using full utilization of these services. Further, the existence of many emergency numbers such as 102, 101, 100, etc. for fire, police services, and other emergency service providers creates a confusion among the public as to which number they should call in case of an emergency. This also leads to the delay if the category of emergency is not appropriately identified by the user and the provider. This shows how important it is to have a single number for all emergencies like 911 of Canada, the USA and 112 provided by the developed nations in Europe. In early 2017, the central government of India had recommended adopting 112 as the common number, and by February 2019, they had taken certain steps to implement this common emergency number system throughout the country. Further, data from surveys show that people generally prefer locally available mode of transportation that is immediately available at the site such as auto rickshaws and taxis rather than wait for the ambulances. This may be because of the response time of the ambulances, which in India is around 50 minutes, much higher than the standard mean time of 20 minutes (Vasudevan, Singh, & Basu, 2016). The issue may be because the ambulance service providers do not adhere to a standard norm time of 20 minutes for urban calls, 40 minutes for a rural call, and transporting the patient to nearest health care center within 20 minutes after attending him/her. Also, data indicates that ambulances are dispatched only for around 5.5% of the total calls received.

Further, there is nothing recorded in databases for the remaining calls. Also, panel data surveys show that the effectiveness of emergency vehicle services in India has no significant impact on

accidental traffic fatalities. This probably indicates that merely establishing a service system may not benefit the public and society. This also means that awareness training and public campaigns by EMS communities and groups need to be planned systematically and conducted on a periodic basis irrespective of the performance and quality indicators that the EMS service system has put in place to achieve its potential.

Other issues which leads to lowering the effectiveness of emergency medical services in India ("108 in Crisis: Complacency and Compromise Undermine Emergency Services' Potential," 2015) are the unrest among contractual employees and paramedical staff, non-fulfilment of memorandum of understanding among the various parties involved in delivering EMS and lack of proper governance by the various state governments, as well as supervision by the central government. This may be attributed to the phenomenon of moral hazard between the state governments who act as the principal and the contractual emergency service provider who act as the agents. Further, currently, GVK-EMRI being more of a monopolistic service provider, it becomes difficult for the state governments to replace it despite their opportunistic as well as non-compliant behavior, which is detrimental in the development of an effective EMS in India.

### 4.2.2 Policy levers in EMS

In this section, we try to address the major policy levers or public policies that can provide the much-needed emergency healthcare service in India by comparing it with that of Canadian policies. The five factors that are useful in developing public policies are financing, regulation, payment, organization, and behavior.

*a) Financing*

Financing impacts the performance of the emergency health system directly. Generally, insurance (both social and private insurance), community financing, out of pocket payments by the patients, general revenue, informal payments, or mixed methods are used by developing countries like India. But the three main outcomes of financing (Roberts, Hsiao, Berman, & Reich, n.d.), i.e. the amount of wealth available for emergency health care, the body that controls the emergency health care resources and the entity that bears the financial burden, are determined by the type of financing method the country chooses.

In Canada, necessary medicinal and physician services are covered by provincial, federal, and territorial governments and, hence, they are well-organized. This makes it responsible for the respective governments in Canada to play a key role and intervene in the overall nation's health economy. This is in contrast to India where 75% of medical expenses are borne out of patient's pockets (Kobusingye et al., 2005). Thus, policy changes in India need to ensure that there is enough financial protection for emergency medical expenditures for the Indian people by ensuring government's commitment to increase its spending on health, increase insurance as well as risk pooling, and improve quality of both public and private emergency service providers.

*b) Regulation*

Regulation by the government (Gupta & Rani, 2004) is key to the success of an emergency health service system as it monitors the quality of services and timely follows up health hazards by enforcing the sanitary code.

In Canada, healthcare has been the single largest budget item for each of the provinces and represents about 11.1% of its GDP. This roughly transfers to about 6299 dollars per Canadian. Further, paramedics are regulated by the government in some form in seven of its provinces and

territories whereas, in three of its provinces Alberta, Saskatchewan, and New Brunswick, paramedics are self-regulated through emergency health acts.

On the other hand, India spends less than 1.3% of its GDP, which is roughly 1000 Rupees or 15 dollars per Indian on healthcare, which is very low as compared to many nations in the world. Despite the central government's best efforts to clean up moral hazards in the system and corruption, the system is largely unregulated, and the introduction of private sector-led schemes may further impoverish the poorest citizens. Lots of overcrowding does happen in ERs, which have erratic specialists with a lack of training in emergency and paramedic services. Dozens of patients sleep under the closest bus shelter, due to lack of affordability in accommodation.

In sum, Canada's regulatory framework is much more committed as well as healthier and needs to be understood well by Indian health policymakers to overcome its diffused regulatory framework thereby creating better and wealthier Indian citizens.

*c) Payment*

Payment describes how the money for the EMS services is to be paid, for what it should be paid, and how much has to be paid. Payment is an essential component of emergency health services system because payment decisions provide incentives that influence the actions of all the entities and individuals involved in the emergency health care system" (Roberts et al., n.d.).

EMS payments are different across the provinces in Canada though usually, the respective provincial governments are responsible for paying most of the costs, including that of ambulance transportation of the patients living in their provinces. There are some costs like co-payment charge, which is a very minimal amount (say around 45 dollars in Ontario, in some cases even this amount is exempted) that has to be borne by the patient. (Roberts et al., n.d.). In contrast, in

India, the fee for service payment dominates in most of the states. The patients, irrespective of income level, pay out of pockets. This has increased the burden on the patient as well as created the health services overuse. As governments generally have less influence on prices, there is need for reform of the payment system, which should reduce the healthcare expenses of the consumers.

*d) Organization*

"Organization refers to the broad structure of emergency health services, inclusive of ownership, competition, a delegation of responsibilities by the regulating authority or government and coordination among the different providers (Roberts et al., n.d.)."

The emergency health care system in Canada is primarily public, with communities and private service providers also playing a critical role. It has a general backing of the health profession. A few experimental projects were set up in many provinces to try out first contact networks like the Family Health Networks in Ontario and the Groups of General Practitioners in Quebec. Further, the governments favored restructuring the remuneration system for emergency service practitioners. Several reforms, thus, recommended the introduction of patient lists and major investments in information technology, apart from recommending it as a specialty.

Despite the Indian government's efforts to promote emergency health services, more political regulations have been used to wipe out the private emergency services. Further emergency services did not take off well, despite being introduced in the late 1990s (Anthony, 2011) due to severe dominance by certain private players for profit. Further, as EMS was not considered as a specialty in India, a smaller number of physicians, staff, and specialists were trained in this area,

however, the trend is changing currently. Numerous paramedics are getting trained on an annual basis in developed countries like the United States, United Kingdom, Canada, and Australia.

*e) Behavior*

Individual behaviors play a very important and salient role not only in promoting good health but also a quality lifestyle. Roberts et al. (2008) argue that four categories of individual behavior, i.e. treatment-seeking behaviors, health professional behaviors, patient compliance behaviors, and lifestyle and prevention behaviors, need to be considered.

In Canada, governments and the private sector achieve health system goals by influencing these behaviors and people's beliefs, expectations, lifestyles, and preferences through advertising, education, and information dissemination (Hsiao & Li, 2003)."

In contrast to Canada, an average life styled Indian does not know the number he has to dial to get access to the emergency system. This is currently due to the existence of multiple numbered systems but can also be contributed to lack of education, training and information dissemination among the public.

### 4.2.3 Policy Reforms and Improvements for Canadian and Indian EMS

India has achieved significant improvement in emergency healthcare in the past two decades and can learn a lot from Canada, which has been overcoming the challenges it has faced in emergency medical services for a long period. Nevertheless, Canada can still learn some aspects from India. In this section, we describe some of the factors which both countries can learn from each other despite the difference in contexts.

Some of the improvements that can be considered while policies are designed in both Canadian and Indian EMS are:

- Reduce out of pocket costs for individuals.
- Reduce the services in case of overutilization.
- Increase access and care for the poor and aged.
- Match emergency capabilities with the demand and need in all areas, specifically the rural and remote areas.
- Increase appropriate incentives for the service providers.
- Provide Right to Information for access to service providers.

### 4.2.4 What India needs to learn from Canada?

Increased spending on health, specifically on the infrastructure, the service providers, and as well as necessities. As currently, the government of India lags Canada and other countries in its contribution to healthcare. Further, the operations, as well as maintenance of ambulances, need to be standardized across service providers and across all states with standard procurement and contracting processes. The call center toll-free number which is 112, as suggested by Central government, needs to be owned and operated by the center and not outsourced and may need a standard process of operating with a suitable triage implemented in its allocation of ambulances.

Further, one of the main challenges faced by the Indian EMS is coordination of the ambulance services with receiving hospitals. The health facilities to which patients will be taken to can have Memorandum of Understandings (MOUs) which are bipartite (between ambulance service provider and hospital) or tripartite (between government, ambulance provider and hospital), Further, such facilities in no way should refuse patient admission before a certain degree of

stabilization which needs to be clearly defined for different emergencies. Different specialty facilities (For example, stroke, maternal, fire injuries, road accidents, etc.) need to be thoroughly identified and supported with appropriate quality regulations. Training and certification courses for emergency health practitioners, including paramedic professionals and staff through formal courses offered by either medical colleges or private service providers should be accredited. Also, such accreditation to training institutions involved in training various paramedic personnel needs to have international collaboration to evolve as well as keep up to date with advances in technology and processes.

The call centers need to have a comprehensive coordination with the information systems team, which may be either outsourced or managed by the center with interfaces to Geographical Information System (GIS) software integrated with ambulances, maintenance of databases relating to paramedic staff and support staff, and detailed set of data collected with reference to performance indicators.

A legal framework operationalizing the policies and its guidelines along with a governance structure managed by the center and states levels under an appropriate authority (Health Ministry) would strengthen the facilities in public facilities and hospitals apart from regulating private service providers.

The finances, i.e. the capital cost for incorporating the new facilities such as call centers, training facilities, information systems and their maintenance costs at regular period, i.e. once in five years, need to be borne by the central and respective state governments. Further, the operating costs of existing as well as new ambulance service providers which are estimated at around 2500 crore annually for a fleet of 15000 ambulances (Bettignies & Ross, 2004) with a regular increase

need to be borne by the service providers who are provided the contract. Financing new ambulance operators, facility upgradation in public hospitals can be taken up by the government both at the center as well as at the state level.

Competition-based on forecasts and demand should be favored for contracting and bidding as it puts pressure on bidders to control costs while simultaneously being innovative as well as providing high-quality service.

This can make providers to commit and meet standards and requirements continuingly so that it can retain their contract. However, if the competition is increased at decentralized mechanisms, say at the districts-level, it can be problematic to the user as well as the regulator because of increased costs due to duplication of EMS infrastructure. Also, technical difficulties and coordination issues among multiple districts/agencies may fail the EMS system. Hence, care must be taken to divide the state into few regions which are composed of a few districts with a few agencies at the same time avoiding monopolistic agency behavior like Canadian or other developed countries, which are in accordance with economies of scale.

Finally, the local communities and their owners, along with their desire for increased and improved emergency services, will play a major role in its successful implementation.

### 4.3 Public-Private Partnerships

Public-Private Partnership (PPP) is as an umbrella term describing collaborative relationships between public and private actors for the achievement of common goals (Singh and Prakash et al., 2010). Koppenjan (2016) defines “a PPP as a form of structured cooperation between public and private partners in the planning/construction and/or exploitation of infrastructural facilities in which they share or reallocate risks, costs, benefits, resources, and responsibilities.” “PPPs can

be defined as arrangements whereby private parties participate in or provide support for, the provision of infrastructure, and a PPP project results in a contract for a private entity to deliver public infrastructure-based services" (Grimsey and Lewis, 2007). Further, non-profits have effectively provided public services which may not include infrastructure, hence it is appropriate to consider nonprofits as legitimate PPPs. Some common definitions of PPP are given in Table1 (Courtesy, Grimsey and Lewis, 2007).

Despite public procurement challenges faced by the PPP, one of the key reasons that the government prefers PPP in the provision of public services is that it provides innovative services. Further it has flexible financial structure to manage risk efficiently, which enhances quality and improves cost efficiencies (Savas, 2000).

### 4.3.1 PPP in Healthcare

Governments around the world are looking for ways of coping with simultaneously increasing healthcare costs and decreasing governmental budgets (Blanken and Dewulf et al., 2010). Further, also, the problems in contemporary healthcare are, to use Mason and Mitroff's (1981) term, wicked problems that are too complicated for governments to solve individually. Also, traditional public health groups are confronted by limited financial resources, complex social and behavioral problems, rapid disease transmission across national boundaries, and reduced state capabilities (Reich, 2000). At the same time, private for-profit organizations have come to recognize the importance of public health goals for their immediate and long-term objectives and to accept a broader view of social responsibility as part of the corporate mandate (Reich, 2002).

### 4.3.2 PPP in Indian Health Care

In India, the public sector accounts for less than 20 percent of the total healthcare expenditure, which is the lowest in the world, and is less than 1% of the country's GDP. Around 94% of the amount of private expenditure is from out of the pockets and the remaining 6% is the provision's expenditure. This challenge leads the government to consider PPP in the emergency healthcare sector in India (KPMG, 2005).

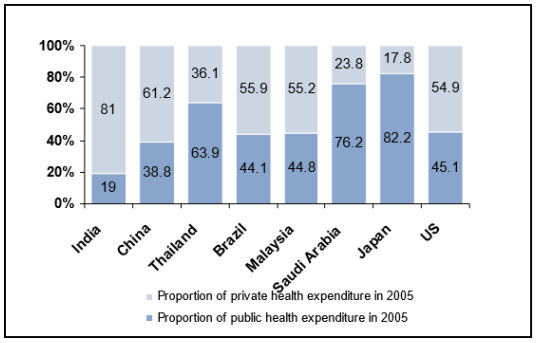


**Figure 3(a): Proportion of health expenditure (Public & Private), (KPMG, 2005)**

Further, with changes in demographics and lifestyle of the population, the disease profile is changing with increased incidences in diabetics and cardiac ailments. Further, since lifestyle diseases require specialized physicians and are expensive to treat, PPP may be a viable solution, which the government can afford to implement across the states after conducting an in-depth study.

Another reason for PPP in emergency health services is that the health infrastructure, i.e. emergency rooms, ambulance services, trained physicians and staff, etc., would require significant capital costs, operating expenses apart from land, which could be better provided when the private sector is partnering with the government.

Finally, the central government is aiming to achieve a sustainable healthcare system through PPP, which it wants to include in a policy whose key aspects are:

- Utilizing private sector to achieve public sector goals
- Liberalizing the insurance sector for better health finance
- Redefining state's role to both provide and finance healthcare services

### 4.3.3 PPP Dimensions and Frameworks in Healthcare

The structure in Figure 3 (KPMG, 2005) shows the possible variations in which PPP models can be configured. PPPs can have private sector as profit-oriented or non-profit oriented. It is seen from the figure that PPPs involve the participation of the public sector at the state or governmental level. Further, it is seen from Figure 3(b) that profit-oriented private partners operate in urban areas whereas nonprofit oriented private partners operate at rural as well as urban areas.

| *Type of Private Partner* | *Content of PPC* | *Process or Service* | *Time range of commitment* | *Contribution of private partner* | *Form of PPC* | *Level of Care* | *Area* | *Type of Public Partner* |
|---|---|---|---|---|---|---|---|---|
| Profit Oriented | Infrastructure | Core process or Service | Long Term | Finances | (Partial) Privatization | Tertiary | Urban | National |
| Non Profit Oriented | Service | Support Process or Service | | Expertise and Finances | Contracting Out | Secondary | | State |
| Idealistic or Altruistic | Management | Management Process or Service | Short Term | Expertise | Outsourcing | Primary | Rural | Community |
| | Innovation | | | | Procurement | | | |

**Figure 3(b): Configurations of a PPP Model (KPMG, 2005)**

Figure 4 shows the different modalities of a PPP (KPMG, 2005).

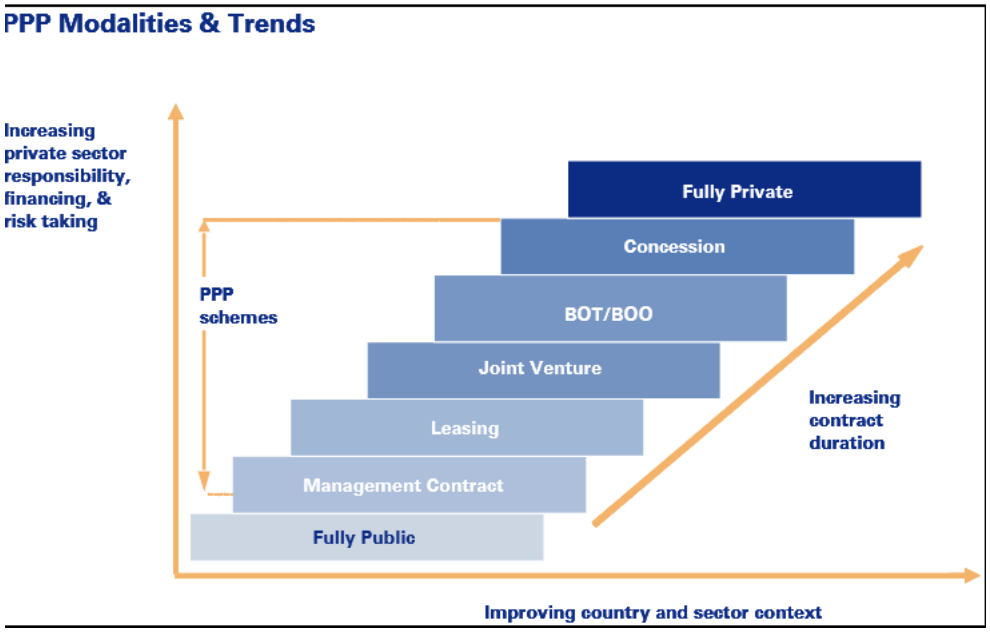


**Figure 4: Different Modalities of a PPP (KPMG, 2005)**

In this study, we mainly consider BOO/BOT types of PPP where the public sector contracts with the private company to design, build, and operate service. Here, the public sector provides the required capital, and the private sector is assigned the operations of the project. The ownership can be transferred to the public or private based on the project needs.

### 4.4 Overall Considerations in Modelling PPP

Value for money (VFM), defined by Grimsey and Lewis (2004) as the optimal combination of whole lifecycle costs, risks, completion time, and quality in order to meet public requirements, is another important consideration, especially for the public sector (Cheung et al., 2009; Grimsey and Lewis, 2004).

Thomas W Ross & Jing Yan (2015) considered using objective governmental functions such as social surplus along with VFM in determining which choice, i.e. public procurement or PPP, is more suitable. Accordingly, they came up with maximizing the objective function of the firm, i.e. to find out the effort required by the firm, which is

$$\max_e \pi = \max_e (1-t)(\alpha - K + \delta e) - \phi(e)$$

Where K is the observable innate cost of the project and includes the cost of labor, materials, etc. $\alpha$ is the lump sum given by the government to the private firm at the start of the contract, e is the effort put by the firm and $\phi(e) = e^2$ is the disutility cost, which is a quadratic function of effort.

Real options are used to value financial incentives of the government (Alonso-Conde et al., 2007). Real options provide flexibilities for PPP by capturing the value of renegotiation (Zhang, 2018) and identifying an effective level of the concession period. (Lv et al., 2014). Lack of good governance has a direct impact on the fulfillment of PPP potential (Hayllar, 2010). During long-term contractual periods, changing government regulation can have a great impact on managing risks (Wibowo and Alfen, 2015).

### 4.5 Game Theory Models

The modeling approach in this study lays its foundations on studies by Ramy Elitzur and Arieh Gavious (2001) who have provided a game theory-based model involving a start-up company with three players: an entrepreneur, an angel, and a VC. Their studies address important gaps in the literature and also address relationships between VC and entrepreneur by introducing the angel investor. Further, one of their (Rami Elitzur and Arieh Gavious, 2001) key findings is that

the opportunistic behavior between the entrepreneur and VC leads to the moral hazard problem. Evidence shows that there are rules, roles, strategies, and pay-offs governing PPP procedures. Thus, modeling them as complex games can help to better understand the failures and difficulties. (Peter Scharle, 2002). Hart (2003) states that if the characteristics of the facility are easy to specify, the government should provide the service. He further shows that if the quality of the service is easier to measure, then the choice is between public provision and partnerships. Public provision is preferred when the worker's effort is very relevant for the success of the service. Studies (Gregory Michael G.M. Kennedy, 2013) have successfully managed to apply the game theory model retrospectively to the Metronet-London Underground case and were successful in influencing decision-making in their renegotiation process. Julie De Brux (2010) shows that renegotiations for improving social surplus can often exist when parties cooperate, which is often known as the ''bright side of renegotiation.'' Besley and Ghatak (2001) show how the state and the voluntary sector interact in delivering public projects. Ho (2009) develops a model for financial renegotiation in PPP projects and its policy implications from a game theory perspective. Medda (2013) studies the "allocation of risks in PPP transportation projects using a game theory approach." Ho (2005) also models a "bid compensation decision process as a non-cooperative static game." Akintoye et al. (2004) also applies game theory in PPPs, especially in the phases before and after a preferred bidder is selected. Barr (2007) points out several elements that should be considered when evaluating the effectiveness of a PPP. Hence, suitable elements need to be considered when modeling the effectiveness of a PPP.

### 4.6 Principal-Agent Model

The principal-agent problem helps to state a few policy problems that are fundamental in an integrated framework, when the outcome of the activities of the agent, Q depends on the action taken by agent and state variable, S i.e.

$$Q= f (A, S)$$ (Bergman and Lane, 1990)

Allocation of public services creates principal-agent relationships between the government and the electorate (Bergman and Lane, 1990). Studies (H. P. Tserng et al., 2012) treat "the national PPP unit as an institution by defining it as an endogenous equilibrium outcome of the game in the view of New Institutional Economics (NIE)." The agent-based model helps in modeling complex systems that are adaptive to circumstance, situations, and environment (MacAl & North, 2010). Jennings (2000) considers an agent as one object that emphasizes autonomous behavioral characteristics. Bonabeau (2001) regards an agent to be any type of independent software or model component. Empirical studies indicate that humans are bound rationally, and as the rules of the game change, with complex social structures and interactions (Gigerenzer and Selten, 2001; Janssen and Ostrom ). Agent-based modeling in combination with game theory has been applied since the early 1980s (Axelrod, 1984).

### 4.7 Implications from Literature Review for a Better EMS in India

The following are the implications from the literature and the real world that would help the Indian EMS to progress further from its current position and better serve its citizens.

1) The emergency medical services in India need to sustain the population growth. In order to supply emergency medical services that consistently meet the demand of the Indian population, the EMS system needs to follow an integrated approach of pricing and costing mechanisms (contract design) between the governments and emergency service providers

such that the service providers (agents) and government (principal) are able to provide quality, efficient and effective service to the patients.

2) An integrated approach to an EMS system with competitive allocation- location operational approach to emergency medical services (ambulances) would be mutually beneficial to service providers, government, communities and users of emergency health services as it would improve the quality of services like appropriate ambulance allocations, minimized response time etc. offered by the service providers in a competitive situation.
3) Suitable performance measures like delay of emergency services (ambulance services) for different types of incoming calls (long distance, short distance). The average waiting time for these incoming calls needs to be brought in practice along with input measures like call arrival rates, average service times, and mileage of travel for the different service providers of the integrated system with suitable incentives designed for the extra mile achievers.
4) The EMS system with a suitable triage and cut-off dispatch rule analogous to that implemented by the western countries, but keeping the Indian context in mind, along with an accurate mathematical model deploying queuing strategies that need to address performance characteristics like overcrowding at hospitals would aid the much-needed integration of the fragmented EMS system in India.

### 4.8 Research Gaps Identified from Literature for the Current Study

Despite existing studies on PPPs between the government and private firms, literature does not clearly indicate what happens to service providers and the services they provide when renegotiation fails between them when there is a demand surge, for example, during the COVID 19 pandemic. This may be due to systemic issues that lead to bargaining between the investor

and a private service provider when a relationship exists between them after renegotiation fails, as implied from earlier literature.

This gives need to address the following research questions.

### 4.9. Research Questions.

1) To study impact of financing service providers (both profit and non-profit firms) when there are changing circumstances, for example, a change in economy or polity, or in case of natural disasters like floods, cyclones and epidemics.

2) To study and understand the problems that occur in emerging economies like India which may need mechanisms that inject capital or bridge funds from international investors including the World Bank.

3) To study and provide solutions to the above-mentioned problems and circumstances using strategies like advertising mechanisms that are relevant in economies that need specific redressal from their citizens.

# 5 CONCEPT FORMULATION

To overcome the gaps identified in literature and create an effective emergency medical service system in India, as seen in section (Realization), the following concept formulation method is used.

1) Relevant methods (Quantitative/Game Theory Techniques) for analytical modelling are identified based on literature to bridge existing gaps in funding mechanisms for EMS and are put into practice.
2) Appropriate scenarios are created in consultation with experts in emergency medical services, both in India and Canada, for building models and subsequent analysis.
3) Finally, suitable empirical evidences from the past (after 2000's) are studied and taken as inputs for the parameters involved in obtaining optimal decisions from the models that are formulated for different scenarios.

# 6.0 ESSAY 1

## 6.1 Objectives

To study funding of profit (Corporate)-based service providers who provide emergency medical services in a Public-Private Partnership (PPP).

- When the service provider (the agent) and the government (Principal) are bound together in a PPP contract during emergency situations that need regular attention.
- When the service provider (the agent) and the government (Principal) are bound together in a PPP contract, during natural disasters like cyclones and tsunamis, or a pandemic .i.e. Covid-19, and there is an unprecedented increase in demand of service provision.
    - The service provider (Corporate) and the government renegotiate the PPP contract terms.
    - Renegotiation does not occur between the service provider (Corporate) and the government and the service provider (Corporate) get into a relationship with an investor based on government intervention.

## 6.2 The Model

### 6.2.1 Key Players

The key players are

- Service Provider (/Social Entrepreneur) (SP)(Corporate/Non-Profit)
- Government
- Investor

### 6.2.2 Setting

Our setting involves an EMS provider (SP) who is risk-neutral and can be of two types (corporate/ non-profit, Refer Figure 1.0 ) and is in a PPP contract with the central government, who is also a risk neutral player. The goal of SP and government is to offer high-quality equitable emergency health service for the welfare of its citizens. A total of 5 scenarios occur in this principal (government)-agent (service provider) game. One of these scenarios involves another party, an investor who funds the SP when the renegotiation

efforts fail between the government and the SP due to unprecedented rise in demand. The timeline of the game is given below.

### 6.2.3 Timeline

The timeline is given in Figure 5 below.

**Figure 5: Event Timeline**.

The event timeline comprises of the following events.

1. Government decides on competitive bids for Service Provider (SP).

2. Government selects the SP and provides Investment I.

3. SP accepts or rejects.

4.If SP accepts and puts an effort e, go to step 5; or if SP rejects, the government selects next SP, and go to Step 1.

5. Contract is executed and pay-off is realized.

6. Nature acts and there is unprecedented rise in demand (e.g. Rise in Covid cases) for emergency service happens.

7. SP renegotiates with government for new investment based on a suitable mechanism design.

8. If government accepts, it provides a new I* to SP with share β towards renegotiating charges and if it rejects, go to step 11.

9. If SP accepts, it puts effort e*, go to step 10 or if SP rejects, go to step 8 for renegotiation.

10.Contract is executed and pay-off is realized.

11. Government selects an investor, sets up a share δ of SP's payoff to the investor.

12. Investor accepts or rejects. If the investor accepts, he invests an amount $I_{vc}$(>=I*) or if he rejects, go to step 11.

13. SP accepts or rejects, if he accepts, he puts a new effort e or SP rejects, go to Step2.

14, Contract is executed and payoffs are realized.

**Figure 6: Ordered play of Events in Timeline**

### 6.2.4 Assumptions

- All the players are risk-neutral. (It easy to change the model to include risk-averse players or a combination of risk-averse and risk-neutral players).
- All the players emphasize equal service output as EMS is more humanitarian.
- If the SP needs further funds and investment, due to the nature/change in demand, it can approach a VC firm with the help of the government.
- The government can take into account some target rate of investment for post-contract investment, $\nu$ (Mason & Harrison, 2002).
- VC takes into account a specific rate of return, $\omega$ (Manigart et al, 2002).
- Effort e is observed only by the social entrepreneur/SP.
- The agent operates in perfect competition and has a reservation utility $\bar{U}$ .
- The government can monitor the benefits/outputs.
- There are two types of effort, observable effort $a$ and unobservable effort $e$ ,which are given as below
    - $z \equiv e + a$
    - Unobservable effort $e =$ two levels, $e_H, e_L$ where $e_H$ denotes effort at higher level and $e_L$ denotes effort at lower level

- $p^H$ is the probability for executing high effort by the service provider who is risk-neutral? We have assumed $p^H$ = 0.5 based on binomial short rate model. (Ho, T.S.Y & Lee, S.B. (2004)).
- Effort is costly (based on Boehm's cocomo model) and it follows the below quadratic equation according to Aghion:

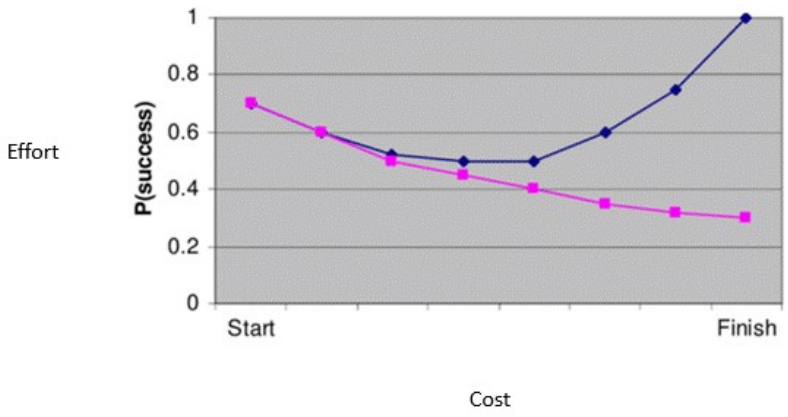


**Figure 7: Plot of Cost-Effort(CoCoMo)**

- $C(e,a) = \gamma * a \quad when \quad e < \underline{e} = \left(\frac{\rho}{2}\right) * (e - \underline{e})^2 + \gamma * a$ when $e \geq \underline{e}$
- a is contractible effort, $e$ is not contractible but efficient non-verifiable, cost-effective effort. (Aghion & Rey, 2000)

- The tax rate is t and can change over time. In this study, we have taken t as 20% (0.2) according to the current corporate taxes levied on corporations in India.
- The charge for emergency services by government is k= m*r. Here, m is taken as 3 according to a survey report by EMRI and the Health Ministry of India (2012).
- The production function/Output function taken here is that of Cobb-Douglas Function having the form $A * E^{\alpha_1} * I^{\alpha_2}$ where $\alpha_1$ is the elasticity of effort and $\alpha_2$ is the elasticity of capital/

investment. $A$ denotes the efficiency. Value for Efficiency for Emergency Health Services (in India) $A$ =0.7 (Found by averaging monthly efficiencies for all states for the year 2014 EMRI Report, 2014)

- Cost is quadratic function of demand elasticity $\theta i.e(a+b*\theta+c*\theta^2)$ (The values of a, b, c. In the current study undertaken, we find a, b and c by regressing expenditures against demand elasticity for the years 2014, 2015, 2016, 2017, and 2018.), a= 4652586, b=-8152965, c= 3620336).
- Demand Elasticity= (Initial demand (of EMS) - Demand after rise during crisis such as COVID 19, Tsunami) / Initial demand (of EMS).

Cost function dependent on demand elasticity (From Literature, Econometrics paper.) - The cost function is dependent on demand (i.e. demand elasticity) and from literature we find that it is a quadratic function. Further in a service economy like emergency research services (Similar to Hospital function where the cost can be taken as a quadratic function of beds), the cost function depends in a similar fashion on demand elasticity which we have defined earlier. (The Regressed equation of cost vs demand (data from 2015-2020) is attached in the appendix of thesis work.)

- Production/ Output is a decreasing function of demand elasticity $\theta$ i.e. here, we have taken it as $\exp^{-\theta}$ (Here, exp =2.718).
- In contractual situations which involve only the government and service provider, $\pi(I, 0) = \pi(0, e) = 0$ i.e. payoff of SP becomes zero, SP does not provide any service if the government does not make any investment I or the SP does not exert any unobservable effort e.
- In contractual situations involving the investor apart from the government and service provider, we have

$\pi(I, 0, I_{VC}) = \pi(0, e, I_{VC}) = \pi(I, e, 0) = 0$ (Elitzur and Gavious, 2001). In other words, the payoff of SP becomes zero. Thus, SP does not provide any service if the government does not make any investment I or the investor does not make any investment $I_{VC}$ or the SP does not exert any effort.

### 6.2.5 Strategic Decision Variables

e = Unobservable effort needed by the social entrepreneur i.e. SP, has two levels

$$e_H, e_L$$

I = Investment by the government

$\beta$ = Share retained by social entrepreneur/ SP on renegotiation

$\delta$ = share retained by investor (VC) in the case renegotiation fails

$I_{VC}$ = Investment by the Investor (VC)

### 6.3 Base Model for Corporate Service Providers

The base principal-agent model between the government and service provider can be described as the following Principal-Agent (PA) problem: the objective function for the service provider i.e. the agent is given by

Maximize $p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} - (p^H * e_H^2)/2$ ---------- (1)

$e^H$ whereas the objective function of the government is given by

Maximize $p^H * t * r * A * e_H^{\alpha_1} * I^{\alpha_2} + k * p^H * A * e_H^{\alpha_1} * I^{\alpha_2} - I(1+v)$ ---------- (2)

$I$

Subject to following constraints:

The first constraint is the incentive compatibility constraint

$$p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} - (p^H * e_H^2)/2 \geq p^L * (1-t) * r * A * e_L^{\alpha_1} * I^{\alpha_2} - (p^L * e_L^2)/2 \quad \text{---- (3)}$$

And

$$p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} - p^H * e_H^2 / 2 \geq \bar{U} \quad \text{----------(4)}$$

which is also known as the participation constraint.

The first constraint is the incentive compatibility constraint. The incentive compatibility constraint is inclusive because it is universal to an extent that in a PPP contract, the partners involved with the government need to consider public interest before operations commence and are transferred, so that any effort that has been put in during the project is much more than what was needed before the start of contract This is given due consideration based on returns and investment by the government. Due to circumstances that may change i.e. change of governments, emergency conditions (i.e. COVID, Climatic conditions etc.) the effort put in a PPP contract needs to be given due consideration.

The objective function must be optimized with reference to effort. The values of $e_h$ and $e_l$ decide whether the service provider has a probability to get into the action of moral hazard.

So, in a PPP contract when the service provider bids, he must provide that optimal value of the effort that gives him the correct investment capital, and this is huge effort. This is because the government assumes that the service provider is clean and there is no moral hazard involved.

Further, any value higher than this optimal eh is not practical because the government would select the lowest bidder and the service provider would not risk with higher effort levels for fear of losing the contract.

Finally, there is a space and leverage for the service provider to put an effort lower than this effort to become more profitable, and which may not be shared with the government. The risk with which he can afford to do this is with a probability of 0.5. This leads to moral hazard.

Solving the above PA problem using the principle of backward induction, we solve agent's (SP's) problem, first subject to the two constraints using the Karush Kuhn Tucker (KKT) conditions to obtain optimal $e^H$ and then substitute the value of $e^H$ in the Principal's unconstrained problem, we obtain the overall optimal conditions and solution for I and $e^H$ . Thus, we have from the agent's (service provider's) problem:

$$e^H = [(1-t)*r*A*\alpha_1 * I^{1-\alpha_1}]^{1/(2-\alpha_1)}$$

(Refer Appendix Scenario 1)

Solving the Principal's i.e., the government's problem, which is an unconstrained optimization problem:

$$\underset{I}{Maximize}\ \ p^H * t * r * A * e_H^{\alpha_1} * I^{\alpha_2} + k * p^H * A * e_H^{\alpha_1} * I^{\alpha_2} - I(1+\nu) \quad \text{---------- (11)}$$

Applying the first order and second order conditions which indicate that the objective function is concave (Refer Appendix Scenario 2), we have

$$I = \left(\frac{1+\alpha_2}{2*\alpha_2}\right)^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (1-\alpha_2) * \left(\frac{1+\upsilon}{(t*r+k)*(p_H * A)}\right)^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (r * A(1-t)) \quad \text{-------- (15)}$$

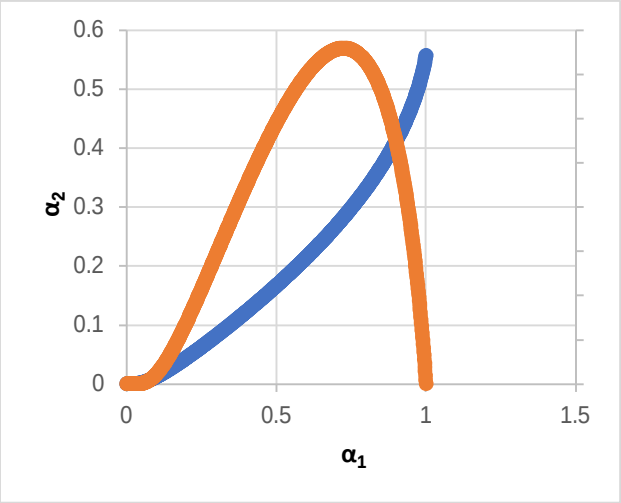


**Figure 8(a)**

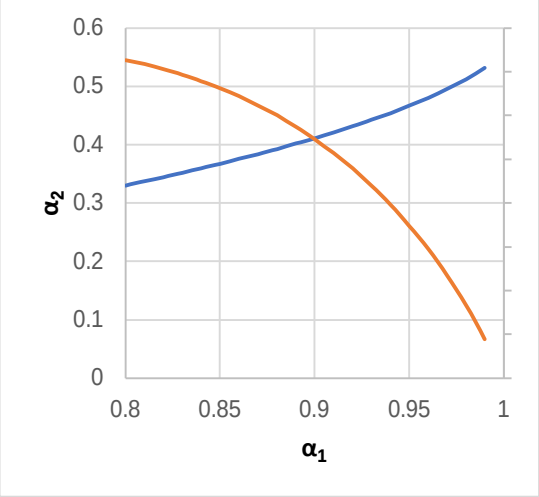


**Figure 8(b)**

**Plot of Investment ( ) and Effort ( )**

Higher changes in effort or investment are required for changes in their respective elasticities, as shown in Figure 8. As demand for this scenario is assumed to be constant and that the equilibrium lies at the intersection of the effort and investment curves. Following this, we arrive at the following propositions:

**Proposition 1**

There are only two types of equilibria in this game for the given real situation:

1) e*= I*=0 at $\alpha_1 = 0, \alpha_2 = 1$
2) (e*, I*) where e*>0, I*>0) at

$\alpha_1 = .90, \alpha_2 = .1$
$as$
$\alpha_1 + \alpha_2 = 1$

Equilibrium 1 is the situation where there is no service. This is obvious since there will be no payoffs at this point.

Equilibrium 2 (Refer to Figure 2(b)) is the situation where the equilibrium investment by the government and the entrepreneur is positive, leading to a positive payoff to the service provider at the end of the contract. This is a situation which benefits both the service provider and the government in a PPP leading to a successful PPP contractual venture.

**Proposition 2**

For the second equilibrium when the service exists,

i.e. (e*, I*) where e*>0, I*>0) at

$$\alpha_1 = .90, \alpha_2 = .1$$

As $\alpha_1 + \alpha_2 = 1$

(All proofs are relegated to Appendix)

Despite the payoffs being positive, there is a possibility of opportunistic underinvestment by the government despite the high effort exerted by the service provider leading to lower payoffs.

During situations where there is a rise in demand of services (EMS), such as crisis situations like COVID 19, decreasing returns to scale may happen. ( alpha + Beta($(\alpha + \beta) > 1$), ( Effort put by SP will increase, despite not much rise in Investment). From literature (Refer Labini, (Labini, P.S., 1995. Why the interpretation of the Cobb-Douglas production function must be radically changed. *Structural change and economic dynamics*, *6*(4), pp.485-504. Refer Page No 490, Econometric Table (Constraints with and without Trends)) we see that this may lead to change of

Cobb Douglas Functions by a decreasing function multiplier. This indicates that using this decreasing function multiplier (such as exponential function theta used in this work, which is known as demand elasticity (d1-d2)/d2)) can result in an Output (Number of cases that are served using Capital investment provided by the government and specified before renegotiation) that is needed by the PPP contract (Quality, access, equity, flexibility and efficiency) which was specified during the contract when the situation was normal.(regular).

### 6.4 A COVID-19-Like Pandemic and Corporate Service Provider - Government Renegotiation

Let $I^*$ be the investment made during renegotiation. Then, the objective function for the service provider is given by

$$\underset{E^H}{Maximize}\ p^H * \beta * (1-t) * r * A * e_H^{\alpha_1} * I^{*\alpha_2} * e^{-\theta} - (p^H * e_H^2 * (a + b*\theta + c*\theta^2)/2 \quad \text{---------(16)}$$

And the objective function of the government is given by

$$\underset{\beta, I}{Maximize}\ p^H * t * (1-\beta) * r * A * e_H^{\alpha_1} * I^{*\alpha_2} * e^{-\theta} + k * p^H * A * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta} - I(1+\nu) \quad \text{------- (17)}$$

Subject to following constraints of the service provider

$$(p^H * e_H^2) * (a + b*\theta + c*\theta^2)/2 - p^H * (1-t) * r * \beta * A * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta}$$
$$\leq (p^L * e_L^2) * (a + b*\theta + c*\theta^2)/2 - p^L * (1-t) * r * \beta * A * e_L^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta} \quad \text{---------- (18)}$$

$$p^H * e_H^2 (a + b*\theta + c*\theta^2)/2 - p^H * (1-t) * r * \beta * A * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta} \leq -\bar{U} \quad \text{---------- (19)}$$

In the above constraints, due to circumstances that may change i.e. change in demand, (i.e. COVID ) the effort put in a PPP contract needs to be given due consideration. This has been incorporated using exponential functions (or similar decreasing functions).

Solving the agent's problem by applying the KKT conditions, we have

$$e^H = [(1-t) * r * A * \beta * \alpha_1 * I^{1-\alpha_1} * \exp^{-\theta} / (a + b*\theta + c*\theta^2)]^{1/(2-\alpha_1)}$$

The proof of this is in Appendix 2.

Now, solving the principal's problem i.e., the government's problem, which is an unconstrained optimization problem for the objective function:

$$\underset{I,\beta}{Maximize} \quad (1-\beta)*p^{H}*t*r*A*e_{H}^{\alpha_1}*I^{*\alpha_2}*e^{-\theta}+k*p^{H}*A*e_{H}^{\alpha_1}*I^{*\alpha_2}*e^{-\theta}-I^{*}(1+\nu) \text{ ------ (23)}$$

Solving the first order with reference to $\beta$ , by back substituting the value of e

$$\beta=(\alpha_1/2*t*r)*[1+k]$$

And then, solving the first order with reference to I, (Refer Appendix 2), we have

$$I^{*}=\frac{[k+(1-\beta)*t*r]^{\frac{1+\alpha_2}{1-\alpha_2}}*R^{\frac{1+\alpha_2}{1-\alpha_2}}}{(1+\upsilon)^{\frac{1+\alpha_2}{1-\alpha_2}}}$$

When we have

Where $\beta$ is substituted from prior equation.

For the objective function to be concave, we see that the first principal minor is negative and the second principal minor needs to be positive at the stationary point (optimal point). Also as $\beta<1$

We have $0<\alpha_1<0.1$

And we also obtain all values of $\beta <= \alpha_1$

From Figure 9, we see that as $\alpha_1$ <=0.1, the plot of effort vs elasticity intersects at a point where

$\alpha_1 = 0.1, \alpha_2 = 0.9$

Which gives us the equilibrium conditions.

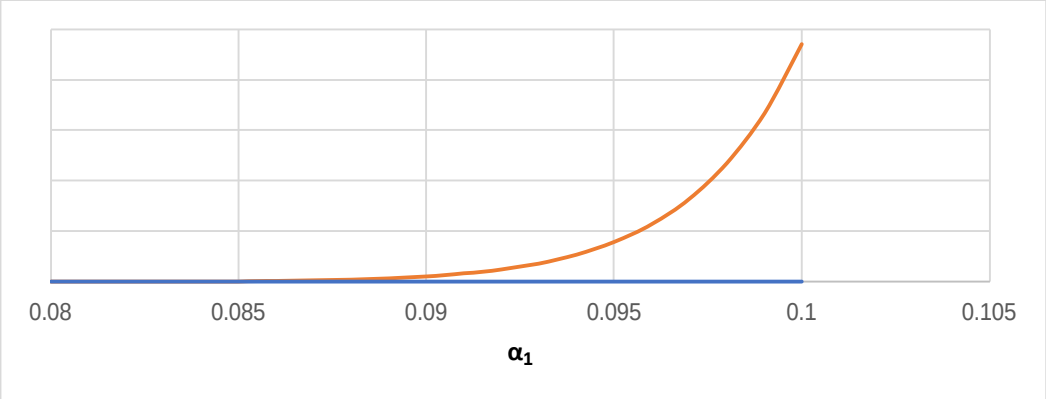


**Figure 9- Plot of Investment ( ) and Effort ( )**

Following this, we arrive at the following propositions:

**Proposition 3**

There are two distinct equilibrium conditions in the current scenario.

They are

$$1)\ \alpha_1 = 0.1, \alpha_2 = 0.9$$

$$2)\ \alpha_1 = (0.....0.08), \alpha_2 = (1.....0.92)$$

The first is an equilibrium point when I>0, e>0 and the payoffs are positive for both the SP and the government. The second is a set of equilibrium points where the firm ceases to exist, as both I=0 and e=0 for this set of points, as seen from Figure 3.

**Proposition 4**

In equilibrium conditions under the current scenario, the payoffs would not be lower as both the players, the government and service provider may tend to exhibit opportunistic behavior, unless there is risk of the service being terminated.

### 6.5 A COVID 19-Like Pandemic when an Investor Funds the Corporate Service Providers

The Agent's Problem i.e. the service provider's problem becomes

$$\underset{e_H}{Maximize}(1-\delta)*(1-t)*p^H*r*A*e_H^{\alpha_1}*I_{vc}{}^{\alpha_2}*\exp^{-\theta}-p^H*e_H^2*(a+b*\theta+c*\theta^2)/2 \quad \text{------ (27)}$$

ST

$$[A*[p^H*e_H^{\alpha_1}-p^L*e_L^{\alpha_1}]*I_{vc}{}^{\alpha_2}*\exp^{-\theta}]*r*(1-t)*(1-\delta)\le(p^L*e_L^2/2-p^H*e_H^2/2)*(a+b*\theta+c*\theta^2)$$

$$p^H*e_H^2*(a+b*\theta+c*\theta^2)/2-(1-\delta)*(1-t)*p^H*r*A*e_H^{\alpha_1}*I_{vc}{}^{\alpha_2}*\exp^{-\theta}\le-\bar{U} \quad \text{- ---- (28)}$$

Due to circumstances that change due to emergency conditions (i.e. COVID, Climatic conditions etc.) the effort put in a PPP contract needs to be given due consideration, incorporating relevant cost functions from literature. (Quadratic function in demand)

The KKT conditions are

$$p^H*(1-\delta)*(1-t)*r*A*\alpha_1*e_H^{\alpha_1-1}*I^{\alpha_2}*\exp^{-\theta}-(p^H*e_H*(a+b*\theta+c*\theta^2)$$
$$-\lambda_1((p^H*e_H^2)/2*(a+b*\theta+c*\theta^2)-p^H*(1-t)*r*(1-\delta)*A*\alpha_1*e_H^{\alpha_1}*I^{\alpha_2}*\exp^{-\theta})$$
$$-\lambda_2((p^H*e_H^2)/2*(a+b*\theta+c*\theta^2)-p^H*(1-t)*r*(1-\delta)*A*\alpha_1*e_H^{\alpha_1}*I^{\alpha_2}*\exp^{-\theta})=0 \text{ -----} \quad (29)$$

$$\lambda_1*[(p^L*e_L^2)*(a+b*\theta+c*\theta^2)/2-(p^H*e_H^2)*(a+b*\theta+c*\theta^2)/2+$$
$$(1-t)*r*(1-\delta)*A*\{p^H*e_H^{\alpha_1}-p^L*e_L^{\alpha_1}\}*I^{\alpha_2}]=0 \quad \text{---} \quad (30)$$

$$\lambda_2*[-\bar{U}-p^H*e_H^2/2+p^H*(1-t)*(1-\delta)*r*A*e_H^{\alpha_1}*I^{\alpha_2}]=0 \text{ ----------} \quad (31)$$

Solving in similar way to the previous situations

$$e_H=[(1-t)*(1-\delta)*r*A*\alpha_1*IC^{1-\alpha_1}*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{1/(2-\alpha_1)} \text{ ----------} \quad (32)$$

The investor's problem is as follows:

$$\underset{I_{vc}}{Maximise}\,\delta*(1-t)*p^H*r*A*e_H^{\alpha_1}*I_{vc}{}^{\alpha_2}*\exp^{-\theta}-I_{vc}(1+\omega) \text{ ----------} \quad (33)$$

Substituting $e_H$ in above unconstrained optimization problem, we have the above set of equations as

$$\underset{I_{vc}}{Maximize}\,Z*I_{vc}{}^{(2*\alpha_2)/2-\alpha_1}-I_{vc}(1+\omega) \text{ ----------} \quad (34)$$

*where*

$$Z=p^H*A*r*\delta*(1-t)*[(1-t)*(1-\delta)*r*A*\alpha_1*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{\alpha_1/(2-\alpha_1)}*\exp^{-\theta}$$

Solving, we have

$$I_{VC} = (\frac{(1+\omega)(1+\alpha_2)}{2.Z.\alpha_2})^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}}$$

If the investor turns down the reinvestment due to the low returns, then $\omega = 0$ and $I_{VC} = (\frac{(1+\alpha_2)}{2.Z.\alpha_2})^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}}$

.

Furthermore, we see that the objective function is concave as the double differential is negative.

For the Government Problem, the objective function becomes

$$\underset{\delta}{Maximize}(1-\delta)*t*p^H*r*A*e_H^{\alpha_1}*I_{vc}{}^{\alpha_2}*e^{-\theta} + k*p^H*A*e_H^{\alpha_1}*I_{vc}{}^{\alpha_2}*\exp^{-\theta} \quad \text{----------(35)}$$

Substituting $e_H and I_{vc}$ from the previous equations in the above equations and simplifying it we have the equation simplifying to the following form

$$\underset{\delta}{\text{Maximize}}\ M*(t*r*(1-\delta)+k)*\delta^{\frac{2*\alpha_2}{\alpha_1}}*(1-\delta) \quad \text{----------(36)}$$

Where $M$ is a constant not affecting the optimal decision variable.

As this is an unconstrained optimization problem and as the second differential of the objective function is negative, the function is concave.

The above unconstrained optimization problem leads to the following optimal solution:

$$\delta = 0.5 + 4.25*\alpha_2 - 1.25*\sqrt{((0.4+3.48*\alpha_2)^2 - 1.024*\alpha_2)}$$

As $0 \le \delta \le 1$, we have $\alpha_1 \le 0.789$, for which the concavity conditions are satisfied.

The equilibrium is obtained at two points, as shown in the Figures 11 and 12 below.

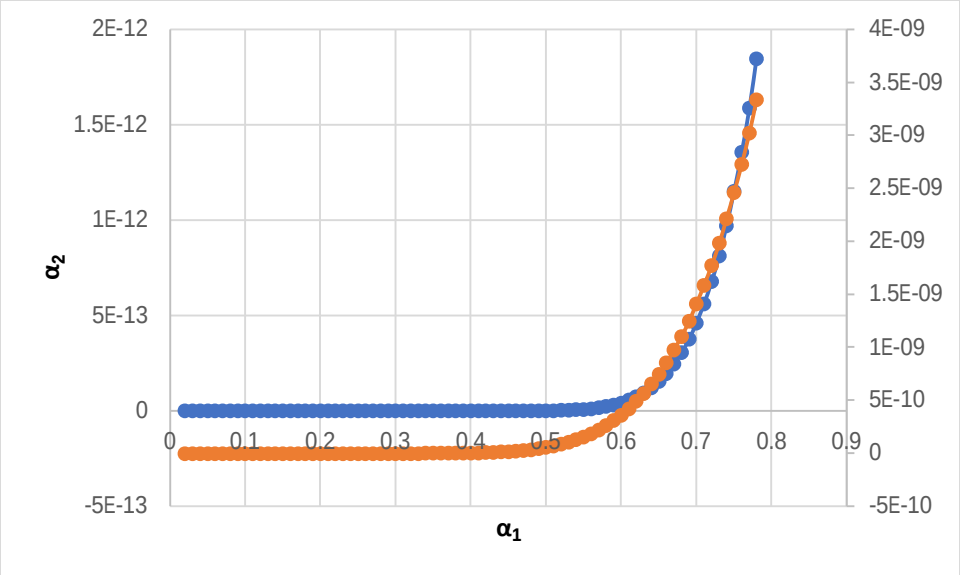


**Figure 10-Plot of Investment ( ) and Effort ( )**

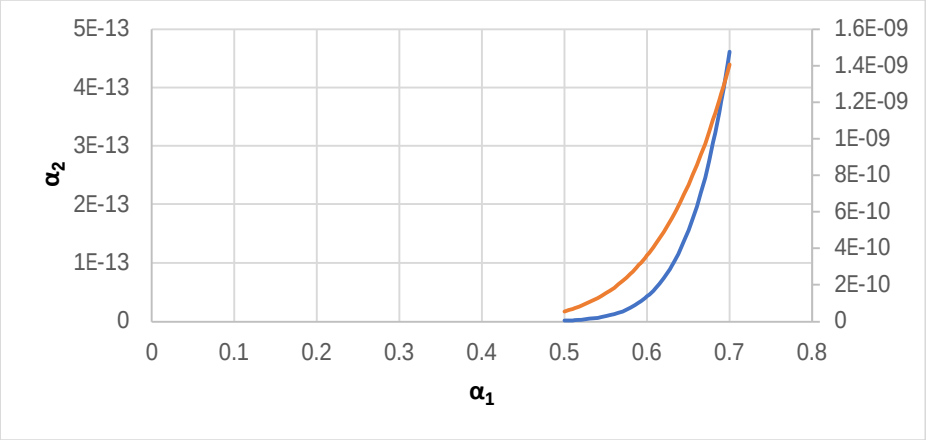


**Figure 11-Plot of Investment ( ) and Effort( )**

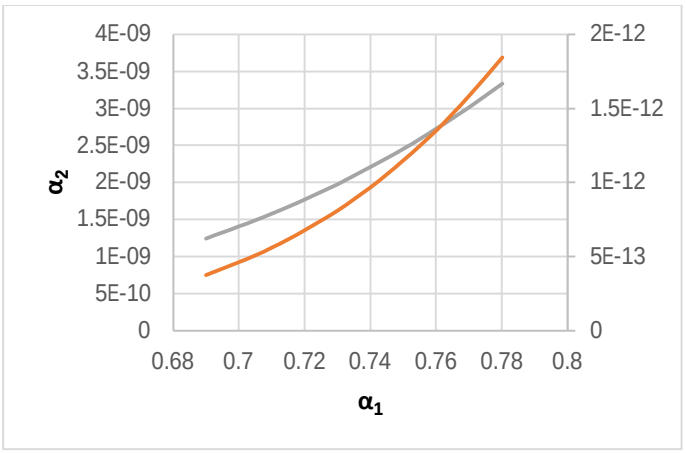


**Figure 12: Plot of Equilibrium Diagram (Investment ( ) and Effort( ))**

Based on the above figures, we arrive at the following propositions:

**Proposition 5**

There are two equilibrium conditions for which $I_{vc} > 0$ and $e > 0$, as shown in Figure 4.

1) The first equilibrium occurs at

$$\alpha_1 = 0.68$$
$$\alpha_2 = 0.32$$

2) The second equilibrium occurs at

$$\alpha_1 = 0.789$$
$$\alpha_2 = 0.211$$

At these equilibrium points, we see with increase in elasticities, there is an increase in the effort and a decrease in investment and both these equilibrium conditions provide positive payoffs to the service provider, investor, and the government.

The results for corporate service providers is summarized in Table 1.

| Player | Service Provider (Corporate) | Government | Investor |
|---|---|---|---|
| **Decision Variable** | $e$ | $\beta, I, I^*$ | $I_{VC}$ |
| **Corporate (Scenario 1)** | $[(1-t)*r*A*\alpha_1*I^{1-\alpha_1}]^{1/(2-\alpha_1)}$ | $I = (\frac{1+\alpha_2}{2*\alpha_2})^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (1-\alpha_2) * (\frac{1+\upsilon}{(t*r+k)*(p_H*A)})^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (r*A(1-t))$ | |
| **Corporate (Scenario 2)** | $[(1-t)*r*A*\beta*\alpha_1* I^{1-\alpha_1}*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{1/(2-\alpha_1)}$ | $I^* = \frac{[k+(1-\beta)*t*r]^{\frac{1+\alpha_2}{1-\alpha_2}} * R^{\frac{1+\alpha_2}{1-\alpha_2}}}{(1+\upsilon)^{\frac{1+\alpha_2}{1-\alpha_2}}}$ $\beta = (\alpha_1 / 2*t*r)*[1+k]$ | |
| **Corporate (Scenario 3)** | $[(1-t)*(1-\delta)*r* A*\alpha_1*I_{vc}^{1-\alpha_1}* \exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{1/(2-\alpha_1)}$ | $\delta = 0.5+4.25*\alpha_2 -1.25*\sqrt{((0.4+3.48*\alpha_2)^2-1.024*\alpha_2)}$ | $I_{VC} = (\frac{(1+\omega)(1+\alpha_2)}{2.Z.\alpha_2})^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}}$ |

**Table 1 – Summary of Results for Corporate Service Providers**

### 6.6 Results and Discussion

#### 6.6.1 Scenario 1

The equilibrium for the first scenario is obtained at

$\alpha_1 = 0.9$
$\alpha_2 = 0.1$

We have used the following principle for obtaining the general equilibrium. Because emergency health services demand depends more on the labor put in by the service provider, the graph shows that effort

increases in its elasticity, which implies an increase in demand of service, as also indicated in section 4. Further, we see that the investment initially rises and then falls with a decrease in its elasticity, which again implies that investment increases and decreases with decrease in demand. But in the current scenario, as the demand is assumed to be constant, we can safely conclude that the equilibrium should lie at an intersection of the effort and investment curves. As previously shown, this occurs at

$\alpha_1 = 0.9$
$\alpha_2 = 0.1$

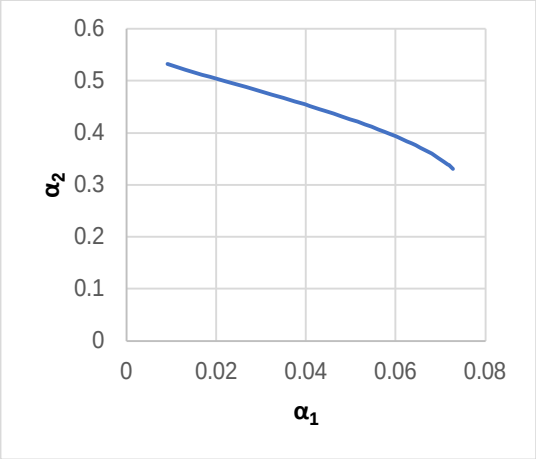


**Figure 13: Plot of Investment (Function of $\alpha_2$ ) vs Effort (Function of $\alpha_1$ )**

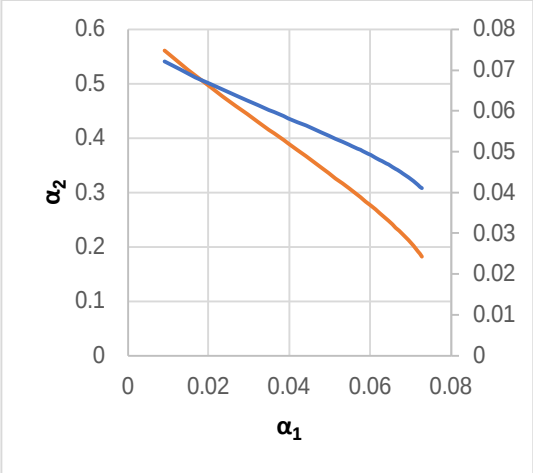


**Figure 14: Plot of SP payoff, Govt. Payoff vs Investment**

From Figures 13 and 14 above, we see that there is a negative relationship between the effort and capital investment around the equilibrium point, which indicates that the elasticity of substitution for the given scenario is negative, providing the insight that labor and investment complement each other. Thus, we can infer that if the demand of the service to be provided increases, there needs to be an increase in the government's investment, leading to an increase in the effort of the service provider, thereby improving citizens' welfare.

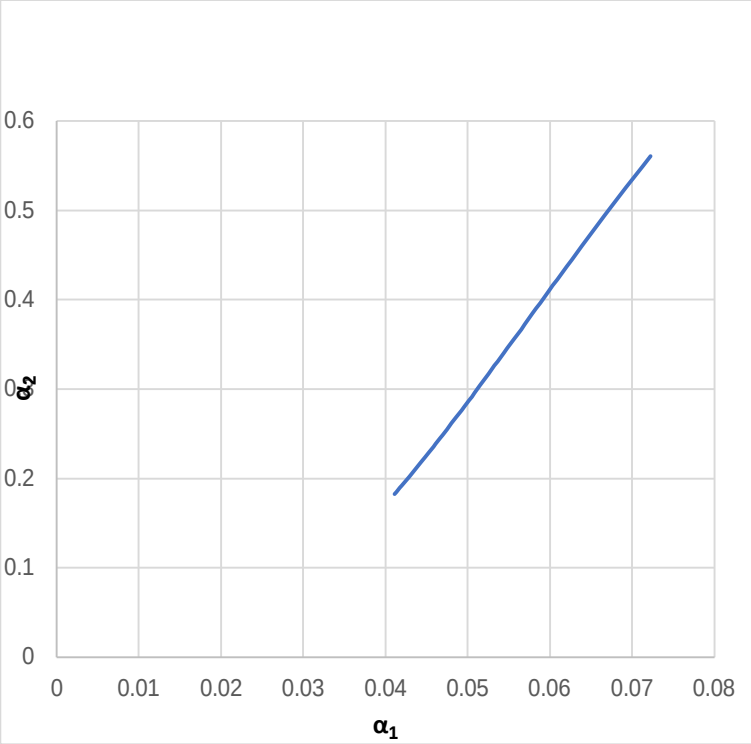


**Figure 15: Plot of Gov. Payoff vs SP Payoff**

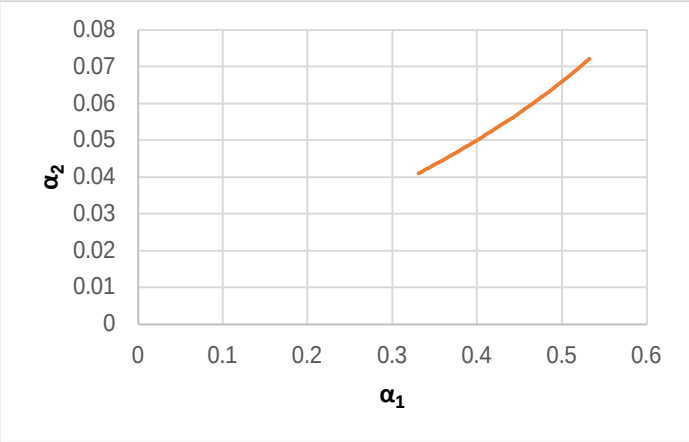


**Figure 16: Plot of SP Payoff vs Effort**

Furthermore, the payoffs of SP and the government are positive, with the payoff of SP increasing with an increase in its effort. As shown in Figures 15, 16 and 17, the government payoff also increases with an increase in SP payoff and, hence, with effort.

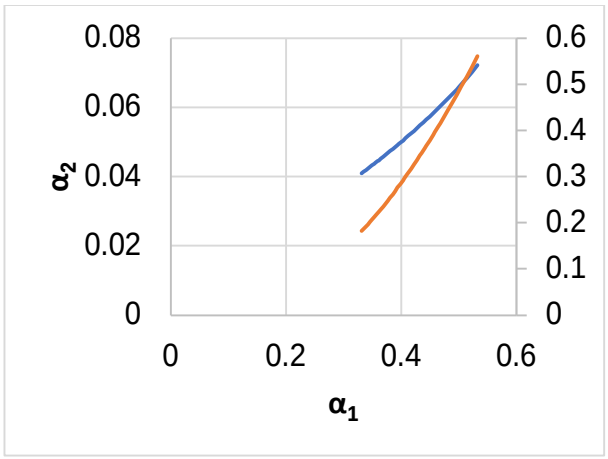


**Figure 17: Plot of SP Payoff, Govt. Payoff vs Effort**

### 6.6.2 Scenario 2

The plot between payoff of the Service Provider and effort, as shown in the below Figure 18, is concave and increasing, indicating that demand would be met, and as well implying that the output quality would be better when the effort is put on a more consistent basis than a fluctuating basis.

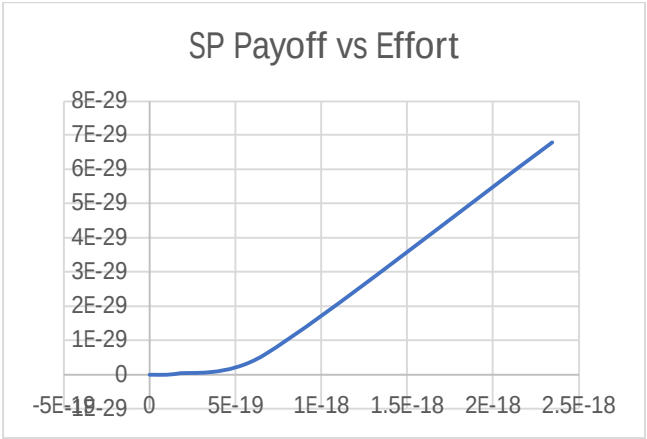


**Figure 18: Plot of SP Payoff vs Effort**

Further, as shown in Figure 19, increased investment by the government when the demand changes leads to an increased effort by the service provider. Furthermore, since the curve is increasing and convex, we

see that marginal effort increases with reference to investment and fluctuating efforts are bound to happen despite increases in the investment.

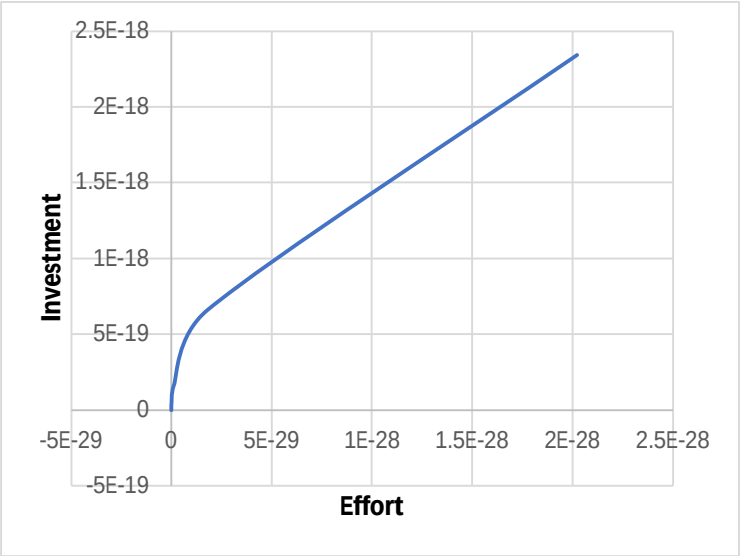


**Figure 19: Plot of Effort vs Investment**

Figure 20 plots the service provider's and government's payoff functions vs elasticity and shows that equilibrium where the service can be provided occurs closer to $\alpha_1 = 0.1, \alpha_2 = 0.9.$ Also, Figures 20 and 21 demonstrate that the payoffs of the government and the service provider are positive in the above-mentioned region of elasticities, showing a linear increasing relationship.

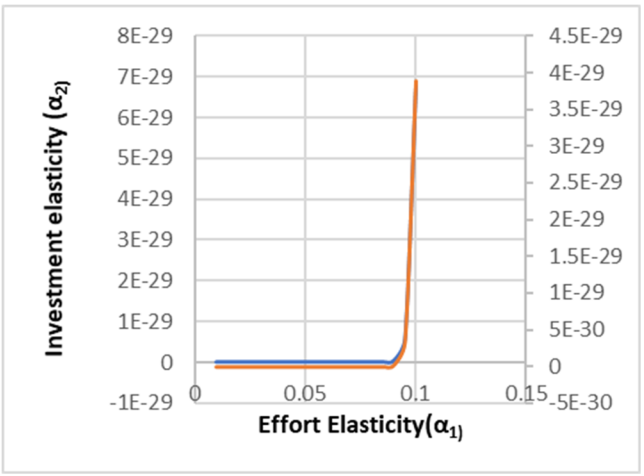


**Figure 20: Plot of Payoff (SP Payoff ( ) and Govt Payoff ( )**

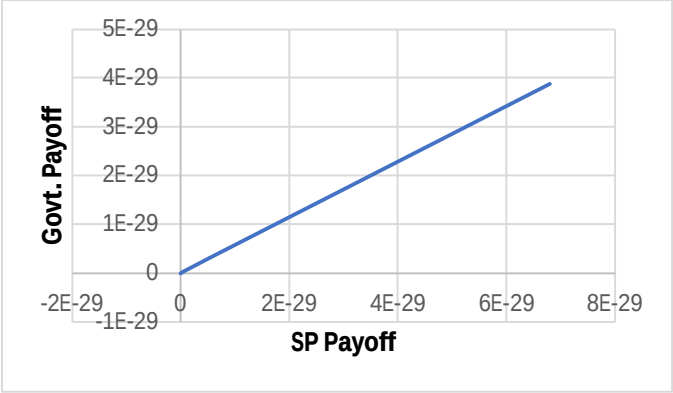


**Figure 21: Plot of Govt. Payoff vs SP Payoff**

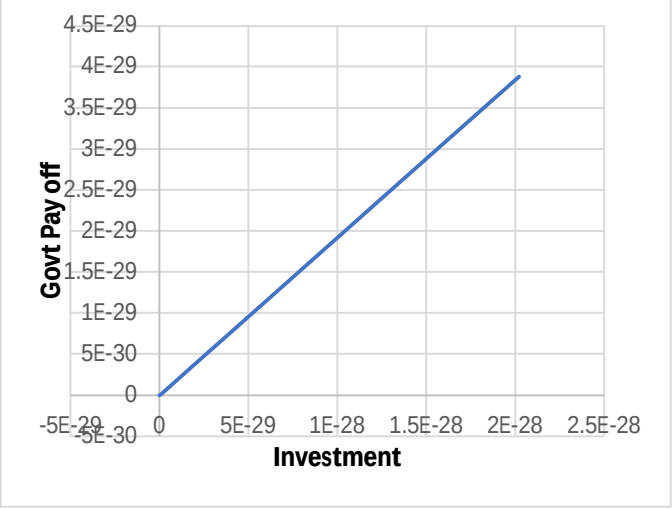

**Figure 22: Plot of Govt. Payoff vs Investment**

Plotting the payoff of government and the investment by government after renegotiation shows a linear increasing relationship unlike scenario 1, where government payoff decreases with increase in its investment, indicating that the government would be more willing for renegotiating the contract with the service provider in the case of an unprecedented raise in demand.

### 6.6.3 Scenario 3

The plot of $\delta$ (The percentage share of service provider's payoff to the investor), which is determined by government, is shown in the Figure 23. Accordingly, the maximum share that an investor can obtain is 18% of the service provider's payoff excluding the taxes. Further, we see that it increases with increase in effort, which increases the service provider's payoff.

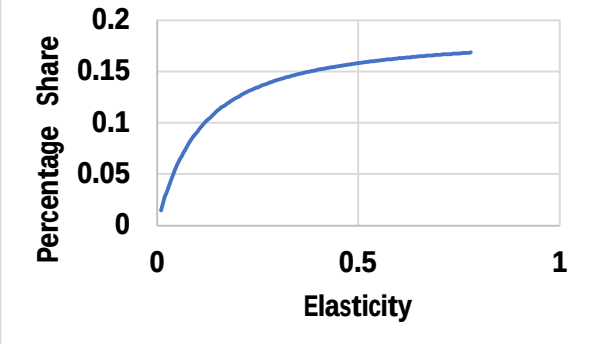


**Figure 23: Plot of Percentage share vs Elasticity**

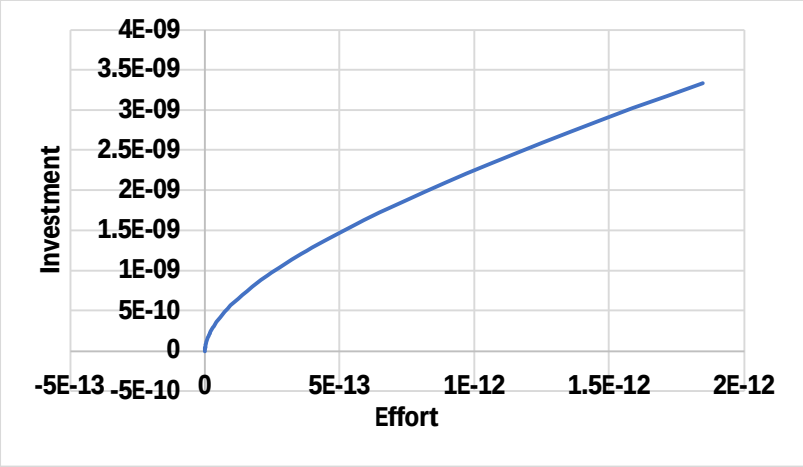


**Figure 24: Plot of Investment vs Effort**

Figure 24 demonstrates that effort must be exerted consistently without much fluctuation with an increase in investment and higher demand, as the curve is increasing and concave. The investor's payoff is positive and increasing in the service provider's payoff in a linear fashion, as shown in Figure 25, indicating that the investment made by theory investor provides him with positive returns, as shown in the increasing linear relationship in Figure 26.

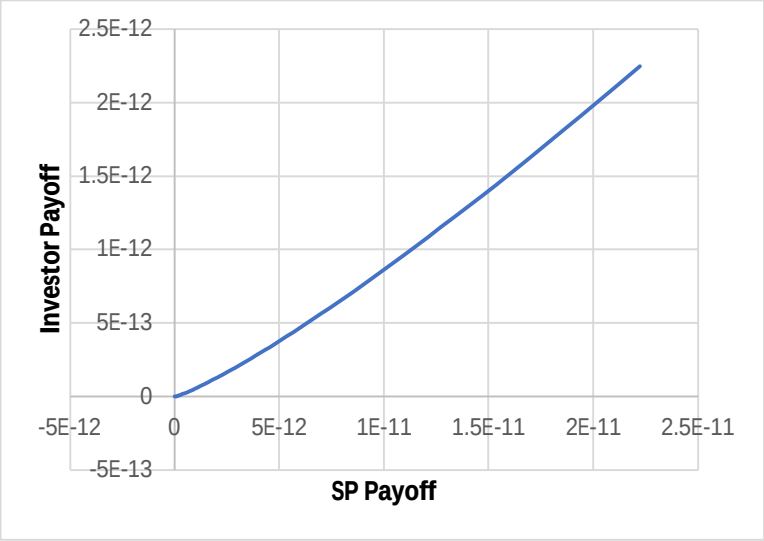


**Figure 25: Plot of Investor Payoff vs SP Payoff**

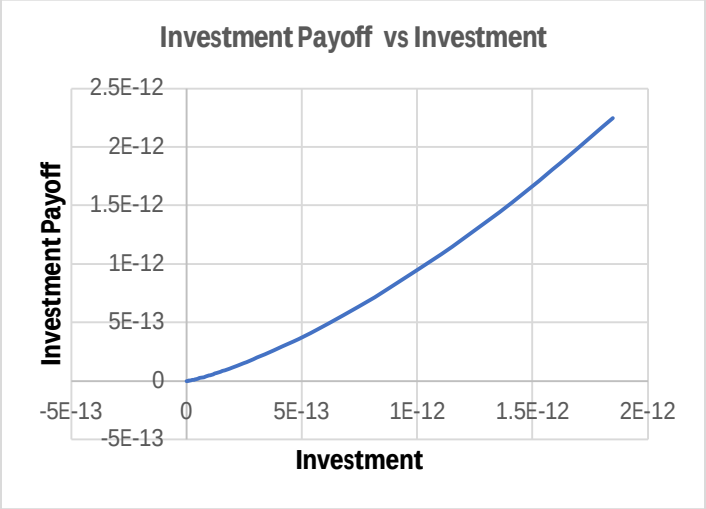


**Figure 26: Plot of Investment Payoff vs Investment**

Figure 27 plots the investor's and service provider's payoffs. As discussed earlier, both have an increasing linear relationship with investment made by the VC.

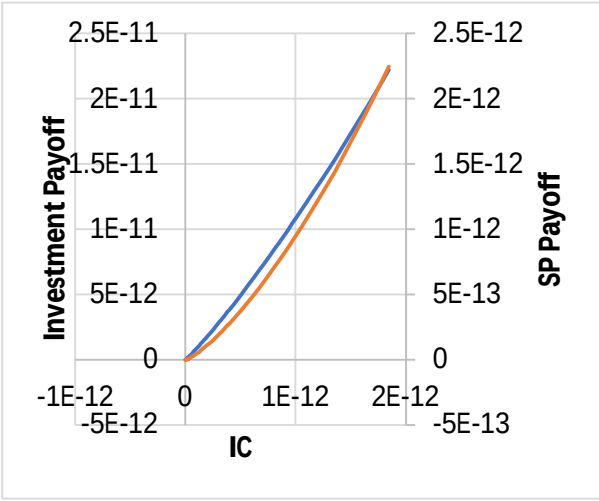


**Figure 27: Plot of Payoff (Inv & SP) vs IC**

The payoff of the service provider is an increasing concave function in effort, indicating that fluctuations in payoff are bound to happen rather than being consistent, as shown in Figure 28.

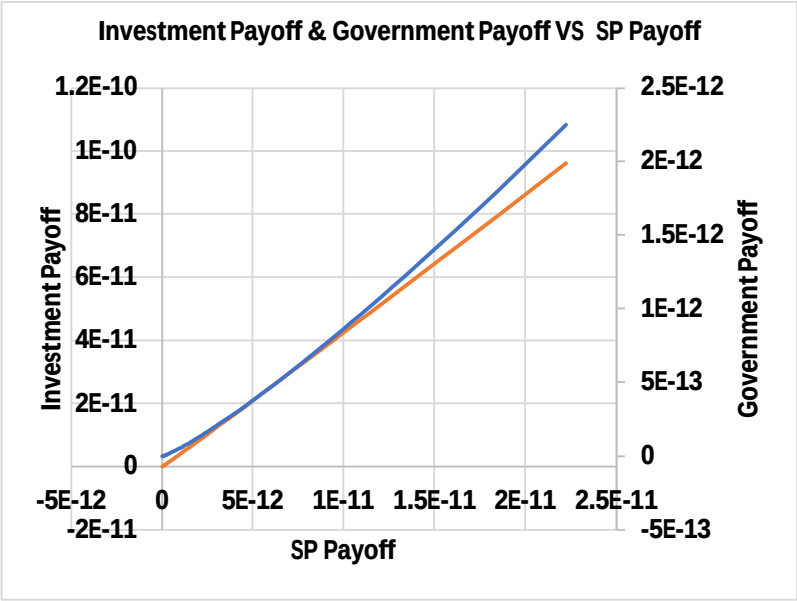


**Figure 28: Plot of Investment Payoff & Government Payoff vs SP Payoff**

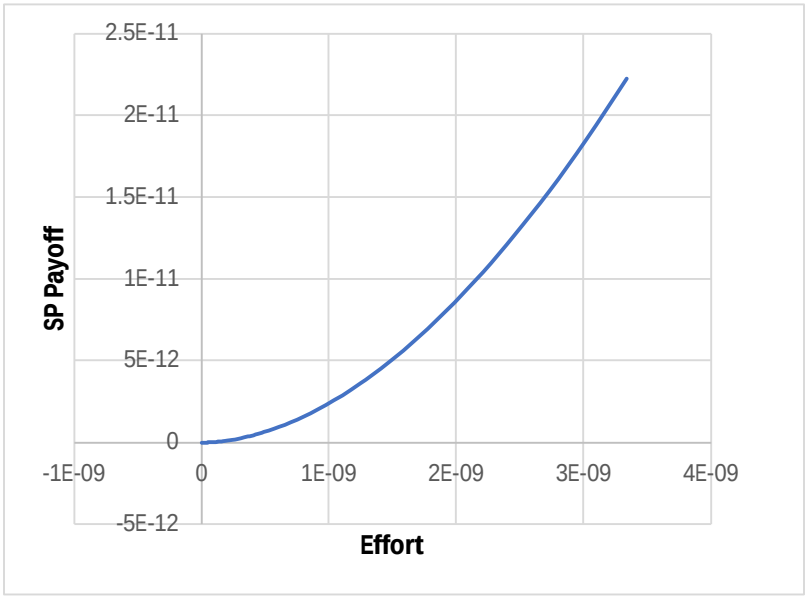


**Figure 29: Plot of SP Payoff Vs Effort**

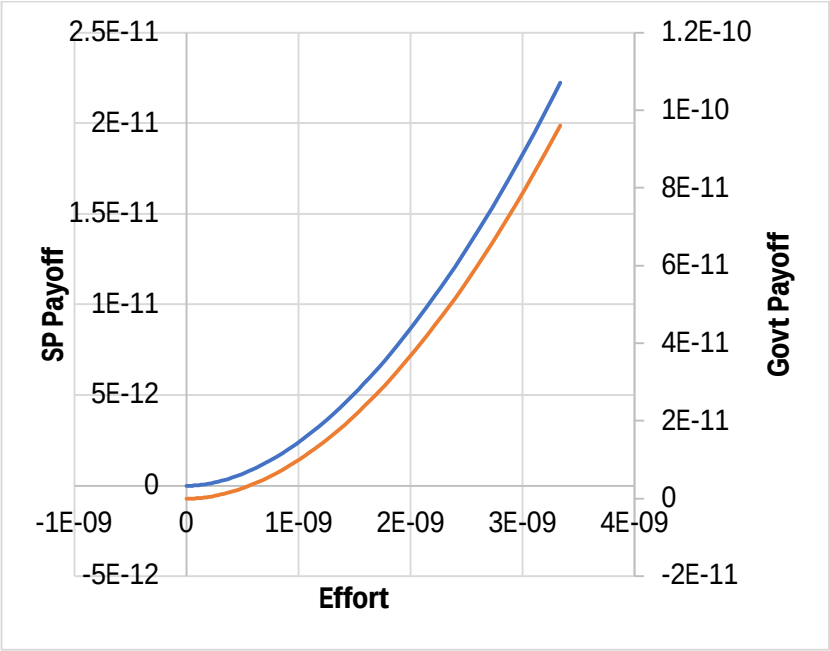


**Figure 30: Plot of Payoff (SP & Govt.) vs Effort**

Figures 30 and 31 depict the relationship of the payoffs of the service provider, government and investor with effort. All these three graphs demonstrate increasing convex functions, thus, indicating consistency in the growth of the payoffs with increase in effort to meet the demand.

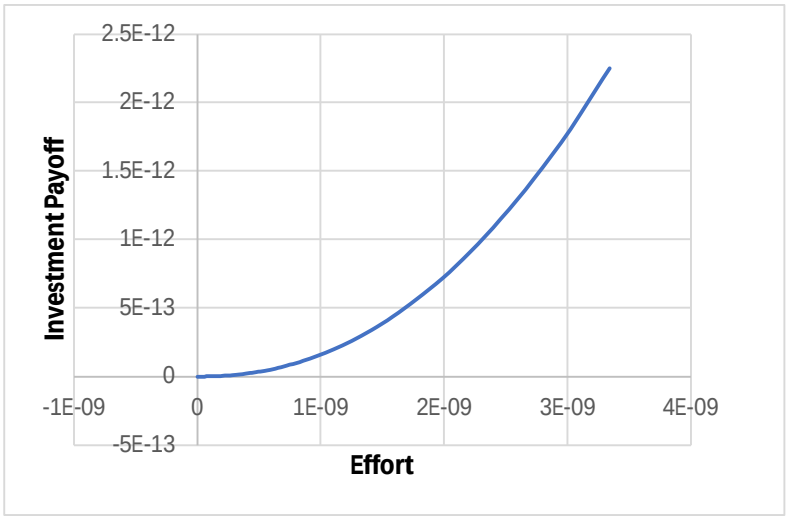


**Figure 31: Plot of Investment Payoff vs Effort**

## 6.7 Managerial Insights

The government's decision on forming a PPP to provide emergency medical services varies on the effort that can be exerted by the service provider in three different situations that the government faces for providing welfare to its citizens. From the above results we see that the service provider exerts an effort in direct proportion to the capital invested by the government in situations where there is a demand change i.e. say during a pandemic, than in a normal situation. This leads to underinvestment by the government during such situation despite lower payoffs as it can expect higher effort exerted by the service provider, leading to better service to the patients. Further, in situations where there is an unprecedented change in demand, there are opportunities for moral hazard to occur, so the government needs to monitor the capital investment that it provides to the service providers. Also, we see that the payoff of the government increases with the service provider's payoff in all the situations, though from the observations, we can infer that in situations 2 and 3, the payoffs are much lower. This can be attributed to the fact that incase of unprecedented rise in demand, the service provider exerts more effort which increases the costs leading to a decrease of their payoff. Further in a situation, where the investor funds the service provider, the government needs to focus on selecting an investor who gives the service provider an opportunity for maximizing their payoffs even in the face of a humanitarian situation like COVID 19. This can be inferred from the results shown in graphs 15, 22 and 24 which provide the insight that the investor's returns do not provide the government the payoffs that it would have obtained without the involvement of the investor.

Further, case studies from 2005 to the current period indicate that health insurance schemes from Yeshaswini like Accord, Sewa and welfare funds yield better profits for service providers who were operating during demand surges during the COVID 19 emergency.

# 7 ESSAY 2

## 7.1 Objectives

To study funding of Non-Profit (/NGO)-based service providers for providing Emergency Medical services in a Public-Private Partnership (PPP).

- When the service provider (the agent) and the government (Principal) are bound together in a PPP contract, during situations which need regular attention.
- When the service provider (the agent) renegotiates the PPP contract term with the government (Principal) due to an unprecedented increase in demand, during situations when there are natural disasters like cyclones and tsunamis or pandemic-like situation, i.e. Covid-19.

## 7.2 Base Model for Non - Profit Service Providers

$$\underset{e}{Maximize}\ r * A * e^{\alpha_1} * I^{\alpha_2} - e^2 / 2 \quad \text{----------} \quad (37)$$

$$\underset{I}{Maximize}\ k * A * e^{\alpha_1} * I^{\alpha_2} - (1+\nu) * I \quad \text{----------} \quad (38)$$

$ST$

$$r * A * e^{\alpha_1} * I^{\alpha_2} - e^2 / 2 \geq \bar{U} \quad \text{----------} \quad (39)$$

Applying the KKT conditions, we obtain the optimal $e$ for the agent's problem

$$e = (\alpha_1 * r * A * I^{\alpha_2})^{1/2-\alpha_1}$$

Solving the Principal's problem, i.e. the government's problem, which is an unconstrained optimization problem and substituting the value of e, the Principal's objective function becomes

$$\underset{I}{Maximize}\ k * R * I^{2*\alpha_2/(2-\alpha_1)} - (1+\nu) * I$$

Where

$$R = A * (\alpha_1 * r * A)^{\alpha_1/(2-\alpha_1)} \quad \text{----------} \quad (40)$$

Taking the first differential and equating it to zero, we obtain optimal solution as

$$I = [\frac{(2-\alpha_1)*(1+\nu)}{(2*\alpha_2)*(kR)}]^{(1-2/\alpha_1)}$$

The second derivative is negative; therefore, the objective function is concave.

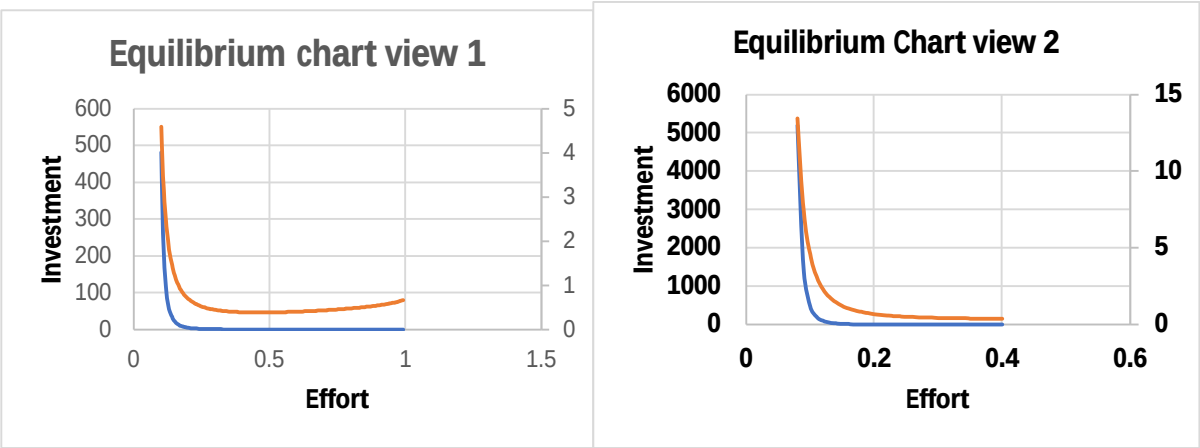


**Figure 32: Equilibrium Diagram for Base Model**

The above Figure 32 shows the plot of investment and effort, leading to the following propositions.

**Proposition 6**

There is a unique equilibrium in this game for the given real situation for constant returns of scale.

1) (E*, I*) where E*>0, I*>0) at

   $\alpha_1 = .08, \alpha_2 = .92$

   as

   $\alpha_1 + \alpha_2 = 1$

Equilibrium situation occurs at I > 0, e>0 leading to a positive payoff to the service provider at the exit of contract.

**Proposition 7**

For $I > 0,\ e > 0$, both players tend to exhibit opportunistic behavior around the equilibrium position for constant, as well as decreasing returns of scale.

### 7.3 A COVID-19-Like Pandemic with Renegotiation by a Non-Profit Provider

The objective function of the service provider becomes

$$\underset{e}{Maximize}(1-\Delta)*r*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}-\frac{e^2}{2}*(a+b*\theta+c*\theta^2) \quad \text{----------} \quad (41)$$

Whereas the objective function of the government becomes

$$\underset{I}{Maximize}\,\Delta*r*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}+k*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}-I^*(1+\nu) \quad \text{----------} \quad (42)$$

Applying the KKT conditions for solving the agent i.e. the agent's problem first, we have

The optimal value of e= $((\frac{1-\Delta)*\alpha_1*r*A*I^{*\alpha_2}*e^{-\theta}}{a+b*\theta+c*\theta^2}))^{1/2-\alpha_1}$

Substituting the above value of e in Principal problem, i.e., government's problem, we have

$$\underset{I,\Delta}{Maximize}\,R*(\Delta*r+k)*I^{2*\alpha_2/(2-\alpha_1)}-I^*(1+\nu) \quad \text{----------} \quad (43)$$

Where

$$R=A[\frac{(1-\Delta)*r*A*\alpha_1*e^{-\theta}}{a+b*\theta+c*\theta^2}]^{\alpha_1/(2-\alpha_1)}*e^{-\theta}$$

Solving the above unconstrained optimizing problem for the government with reference to the decision of Investment I, we have

$$I^*=(\frac{1+\alpha_2}{2*\alpha_2})^{\frac{-(1+\alpha_2)}{1-\alpha_2}}*(\frac{1+\nu}{\Delta*r+k})^{\frac{-(1+\alpha_2)}{1-\alpha_2}}*(1/R)^{\frac{-(1+\alpha_2)}{1-\alpha_2}}$$

Similarly, solving for $\Delta$ , we have

$$\Delta=\frac{(1-(\frac{\alpha_1}{2*\alpha_2})*k)}{(1+(\frac{\alpha_1}{2*\alpha_2})*r)}$$

The conditions which satisfy $\Delta$ are $0 \le \alpha_1 \le 0.3$.

The objective function's Hessian's 1st principal minor is negative and the second principal minor is positive, demonstrating it is concave function with reference to both I and $\Delta$.

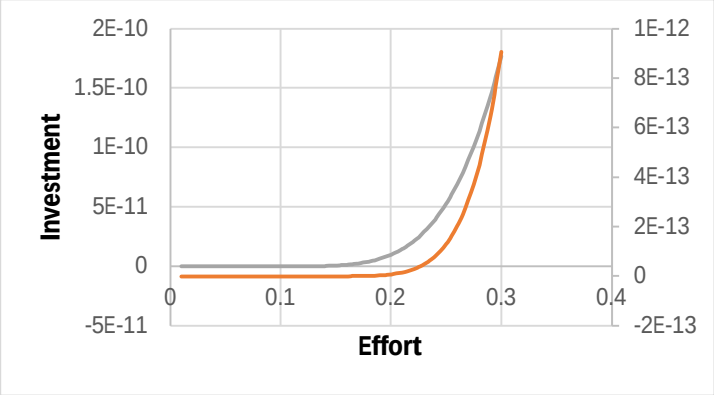


**Figure 33: Equilibrium Diagram When There is Surge of Demand**

Figure 33 shows that with an increase in elasticity the effort increases and investment increases for the region $0 \le \alpha_1 \le 0.3$. This is followed by the following propositions.

**Proposition 8**

For e>0, I>0, there exist a unique equilibrium for which the service provider successfully renegotiates and executes the contract, as follows

$$\alpha_1 = 0.3, \alpha_2 = 0.7$$

**Proposition 9**

For I>0 and e>0, both players (the government and service provider) tend to exhibit opportunistic behavior around the equilibrium point.

The results for non-profit providers are summarized in Table 2.

| Player | Service Provider (SP) | Government |
|---|---|---|
| **Decision Variable** | **e,** | $\Delta$ **, I, I**$^{*}$ |
| **Non-Profit (Scenario 4)** | $e = (\alpha_1 * r * A * I^{\alpha_2})^{1/2-\alpha_1}$ | $e = ((\frac{1-\Delta) * \alpha_1 * r * A * I^{*\alpha_2} * e^{-\theta}}{a + b * \theta + c * \theta^2}))^{1/2-\alpha_1}$ |
| **Non –Profit (Scenario 5)** | $I = [\frac{(2-\alpha_1) * (1+v)}{(2 * \alpha_2) * (kR)}]^{(1-2/\alpha_1)}$ | $I^{*} = (\frac{1+\alpha_2}{2 * \alpha_2})^{\frac{-(1+\alpha_2)}{1-\alpha_2}} * (\frac{1+v}{\Delta * r + k})^{\frac{-(1+\alpha_2)}{1-\alpha_2}} * (1/R)^{\frac{-(1+\alpha_2)}{1-\alpha_2}}$<br><br>$\Delta = \frac{(1 - (\frac{\alpha_1}{2 * \alpha_2}) * k)}{(1 + (\frac{\alpha_1}{2 * \alpha_2}) * r)}$ |

**Table 2-Summary of Result of Non-Profit Providers**

### 7.4 Results and Discussion

#### 7.4.1 Scenario 4

Plotting effort vs investment in Figure 34 shows an increasing convex curve, indicating that there will be fluctuations in the effort put by the service provider, despite an increase even if the government pumps in more investment.

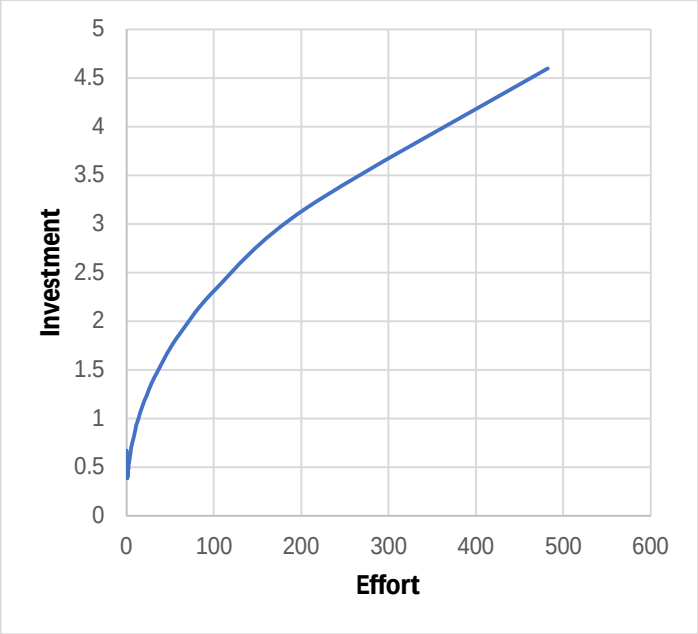


**Figure 34: Plot of Investment vs Effort**

**Figure 35: Plot of SP Payoff vs Effort**

Furthermore, the payoff of the service provider increases as demonstrated in Figure 35 by the convex shape of the upward sloping curve. The payoff of the government increases linearly along with the service provider's payoff, as shown in the Figure 36. Similarly, the payoff of the government increases linearly with the investment, as shown in Figure 37, indicating that the greater the investment in the NGO, the more it is beneficial for it, both from the welfare point of view and as well as profitability.

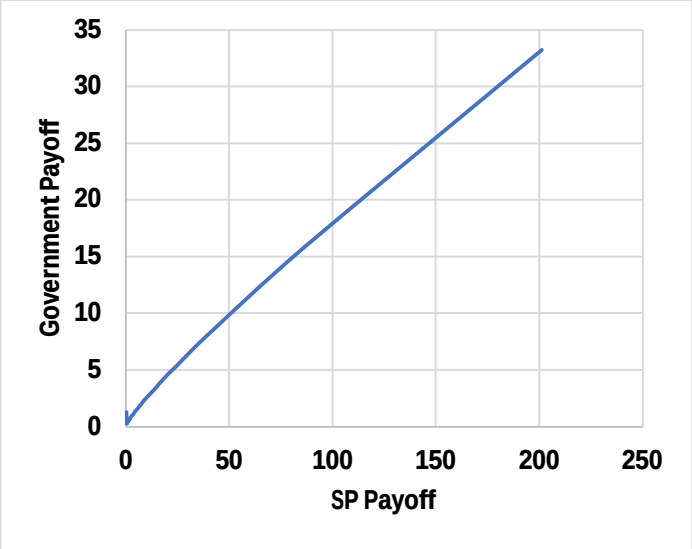


**Figure 36: Plot of Govt. Payoff vs SP Payoff.**

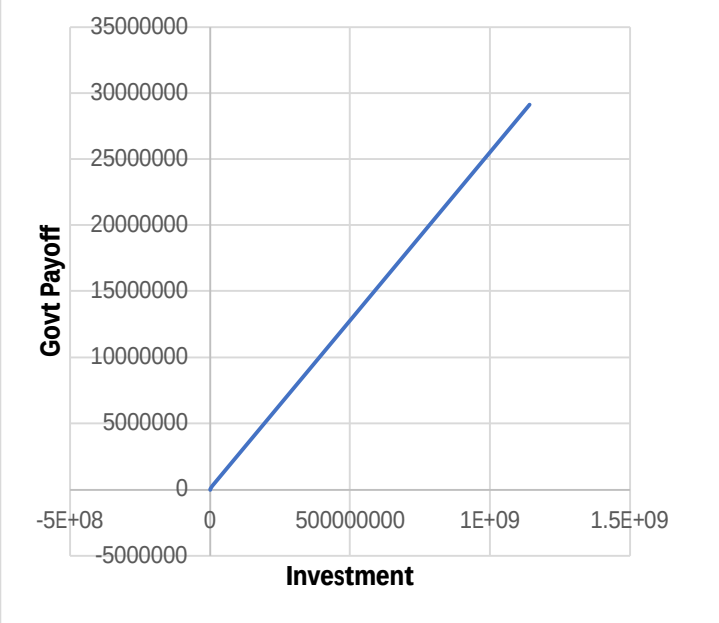


**Figure 37: Plot of Govt. Payoff vs Investment**.

### **7.4.2** Scenario **5**

Figure 38 shows the presence of an increasing convex relationship indicating that there will be fluctuations in the effort put by the service provider, despite an increase, even if the government pumps in more investment after renegotiation, which may affect quality of service and other outputs like equity etc.

However, Figure 39 demonstrates an increasingly convex relationship with effort, as similar to previous scenarios, showing a consistent increase in payoff when the effort put in by the service provider increases.

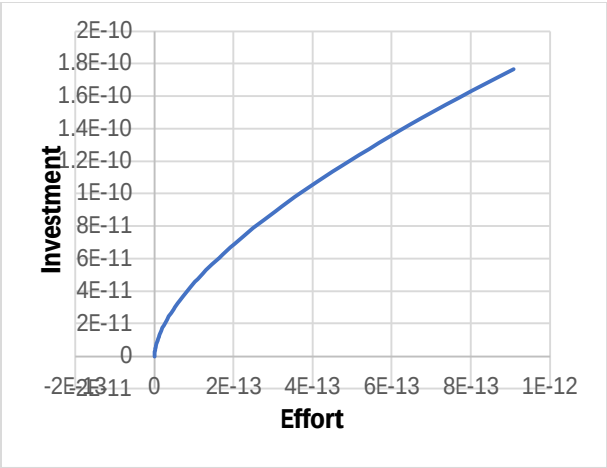


**Figure 38: Plot of Investment vs Effort**

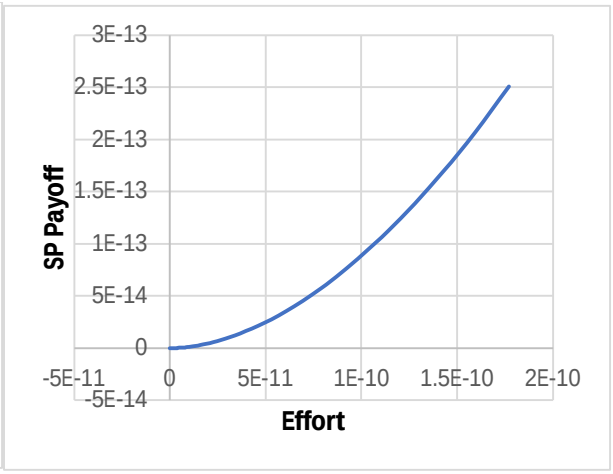


**Figure 39: Plot of SP Payoff vs Effort**

Figure 40 demonstrates a linear increasing relationship between the payoff of the government and service provider. This is expected as from the earlier scenarios.

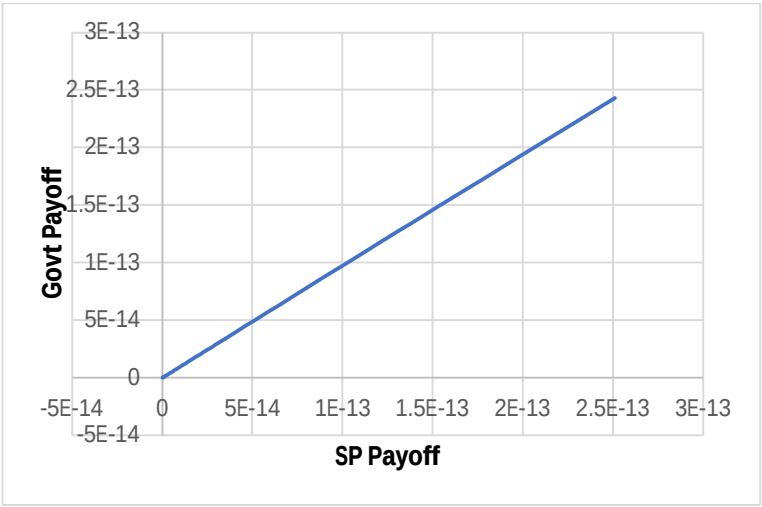


**Figure 40: Plot of Govt. Payoff vs SP Payoff**

The government's reinvestment after renegotiation with the service provider, due to significant changes in demand, depends on the percentage of service provider's payoff that is contributed to the government's payoff. We see from Figure 41 that investment decreases with an increase in percentage. This can be attributed to the fact that the percentage contribution also decreases with

effort's elasticity, which implies that the service provider may not be willing to put more effort if the government charges a greater % of its payoff.

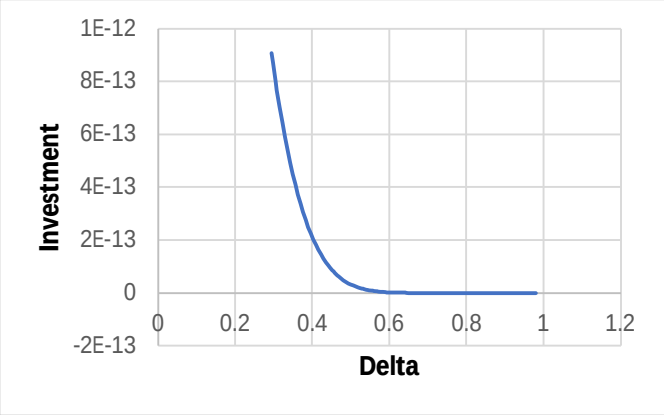


**Figure 41: Plot of Investment vs Delta**

Finally, we also observe from Figure 42 that both the payoffs of the government and service provider increase with an increase in the investment by the government after renegotiation.

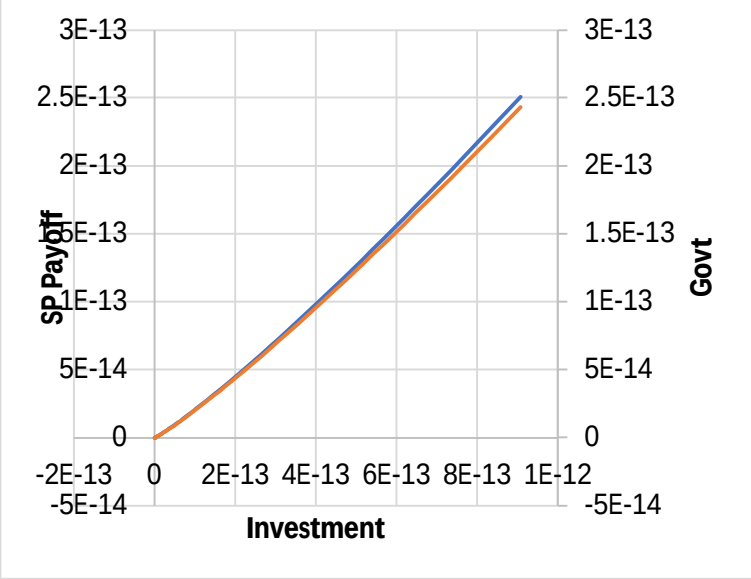


**Figure 42: Plot of Payoff (SP & Govt. vs Investment)**

### 7.5 Managerial Insights

The government may decide to opt for a non-profit service provider in the PPP partnership on a humanitarian basis, if pay-offs is not a deciding factor for investing. Further, we see from graphs 37 and 42 that the payoffs for government increase with the increase in payoffs of the service provider in both the situations. This happens when the non-profit SP renegotiates with the government. We see that the government investment decreases with an increase in the percentage of the payoff. This provides us with the insight that the government prefers investing in non-profit service providers as its pay-off increases with the payoff of the non- profit SP. Further, as seen in subsequent section, non-profit service providers need not spend on advertising costs, which may relieve the service users of a higher price.

Further case studies from Yejaswini indicate that the health economic index can be increased by more than 10% in smaller states than bigger states for certain insurance schemes. This can be integrated with non-profit service providers to alleviate difficulties of the citizens at a lower premium for both joint and individual /nuclear families.

# 8.0 ESSAY 3

## 8.1 Objectives

1) Utilize advertising as a signal for helping citizens (/patients) determine the type of Service Provider (Profit/ Non-Profit Type)

2) Utilize advertising as a signal by service provider to decide the service provision.

## 8.2 Introduction

Service providers of a particular service usually hold a higher edge on information about their services, quality and pricing than the patients who are the users of the service. Service providers for emergency services are of two types, (a) Private service providers who are usually profit-based corporates and (b) Non-governmental organizations that are non-profit-oriented. Most people nowadays are turning to private health providers than NGO's/government-run hospitals due to better infrastructure, quality and service. For services such as emergency services, which are provided by either private service providers or NGOs in PPP contracts, it is not possible for the patients who avail the emergency services to identify whether the service provider is an NGO or a profit-based service provider. Though the service provider may finally maximize their profit, they should be ethically more careful about the patient's wellbeing. In this study, we develop a game theory model and investigate advertising with pricing/cost characteristic as a signal from the service-provider.

## 8.3 Literature Review

A service provider can signal their type by advertising the price for the service, which in the case of emergency health service, can be considered as a credence good (Frank A Sloan & Chee Ruey Hsieh). A credence good is a good whose impact on the consumer's utility is difficult for them to ascertain even if the service has been realized (Darby and Karni 1973, Dulleck and Kerschbamer 2006, Dulleck et al. 2011). Some common issues observed by Jing (2011) in these types of goods are overcharging of service provided and under/over provision by the service provider. Some other examples include auto repair and legal services (Jiang et al., 2011). Fong (2005) shows that when the service provider knows their type, and as well as the condition of the customer, they are prone to cheating. Guo and Jiang (2013) closely examine both pooling and separating

equilibria to rationalize the underlying market phenomena. Standard literature in economics generally assumes that firms exist for profit maximization. But behavior such as being conscientious or altruistic is demonstrated by extensive behavior literature. For example, ethical providers, who are primarily NGOs for humanitarian services such as EMS may derive some utility from the patient's well-being (Ho et al. 2006a,b). Hence, even if the costs are higher than the service charge (i.e. prices) these providers may be fine in service provision (Vanberg 2008). Guo and Jiang (2013) study fairness concerns regarding search goods and show that firm's cost to customers are determined by price and quality. Jang, Ni and Srinivasan (2014) model both social preferences and the key characteristics of multidimensional private information in a credence good market. Through our study, we attempt to contribute to the signaling games involving pooling and separating equilibrium in PPP where the government is undecided about contracting the services to an NGO or profit-oriented service provider.

## 8.4 The Model

The signaling game between the service provider and patient can be described as below and as shown in Figure 43.

1) Nature chooses SP type from profit-oriented firms or non-profit oriented firms.
2) SP chooses whether or not to advertise or follow a mixed strategy and signals to the patients for provision of service.
3) Patients accept or reject the service.
4) SP accepts or rejects the service provision based on payoff.
5) Service is realized.

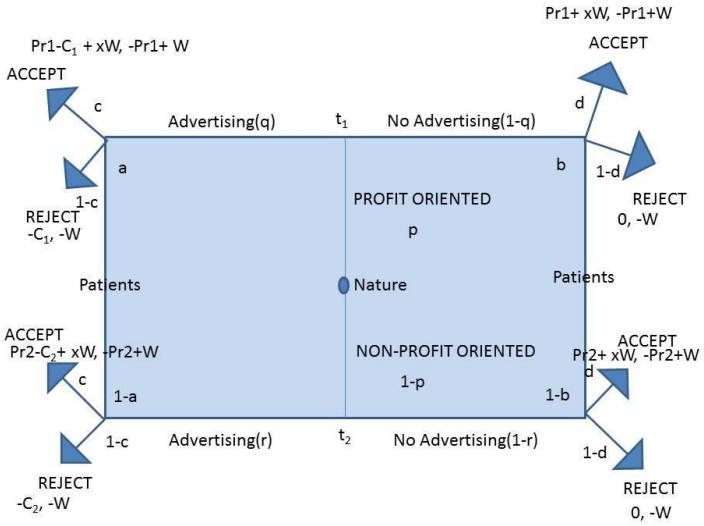


**Figure 43-Signaling Game between the SP and Patient**.

### 8.4.1 Description for the parameters in the Game

p- Probability that SP is profit-oriented.

q- Profit-oriented firm's strategy (Probability that profit-oriented firm advertises)

r- Non-profit-oriented firm's strategy (Probability that the non-profit-oriented firm advertises)

a- Patient's belief about the SP being profit-oriented upon observing an advertising signal

b- Patient's belief about the SP being non-profit oriented upon observing no advertising signal

c- Patient's strategy after observing advertising (Probability that patient accepts the service)

d- Patient's strategy after observing no advertising (Probability that patient accepts the service)

Pr1- Service charge of the profit-oriented firm

C1- Cost for advertising of the profit-oriented firm

Pr2- Service Charge of the profit-oriented firm

C2- Cost for advertising of the profit-oriented firm

W – Well-being (/Welfare) provided by the service to the patient

x- A positive constant denoting degree of social preference because of the care the SP has taken

for the well-being of the patient.

### 8.4.2 Assumptions

Both types of SPs care in equal degree about the well-being of the patient.

Both types of SPs provide the same well-being (Welfare) to the patient.

In case the patient does not want the service from the service provider and rejects it, the service provider does not lose or gain utility (Well-Being) of the patient.

## 8.5 Solution Method for the Signaling Game

The above signaling game can be solved using a Bayesian-Nash equilibrium approach based on the fundamental principles of Nash equilibrium, which states that none of the players have an incentive to deviate from the equilibrium strategy. An additional principle in this type of signaling games is that the players form beliefs about the sender (in the study, the service provider) based on the Bayesian Process. In signaling, Bayesian Equilibrium is preferred over sequential equilibrium as properties and solutions for sequential equilibrium is not the same as the Bayesian equilibrium beliefs. There are three classes of this type of equilibrium i.e. Bayesian Nash equilibrium (Separating, Pooling and Semi-Separating) and we see under what conditions they can be achieved (/not achieved).

### 8.5.1 Separating Equilibrium

1) Consider the following separate strategy, i.e., when SP is a profit-oriented firm and advertises; and as well as SP is a non-profit-oriented firm and does not advertise.

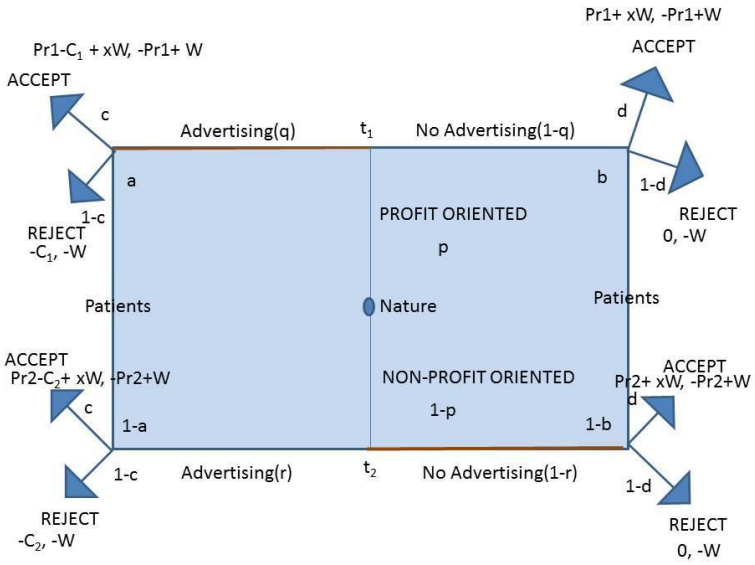


**Figure 44- Separating Equilibrium**

The patient after observing the service provider's type can form and update their beliefs about the service provider, as shown in Figure 44. Applying Bayes rule to the above situation, which is a separating strategy profile i.e. advertising and non-advertising for the informed player i.e. the service provider:

We observe that here a = 1 because we apply Bayes Rule

$a = \frac{p*q}{p*q+(1-p)*r}$ and for the above separating strategy profile q=1, r=0

Intuitively, this indicates that after the patient observes the advertising announcement, he/she assign full probability that such an announcement comes from a profit-based service provider.

b =0 because

b = $b = \frac{p*(1-q)}{p*(1-q)+(1-p)*(1-r)}$ and for this, we substitute q=1, r=0,.

This implies that the patient observes that if there is no advertisement announcement, the service originates from a non-profit-based service provider and cannot originate from a profit-based service provider.

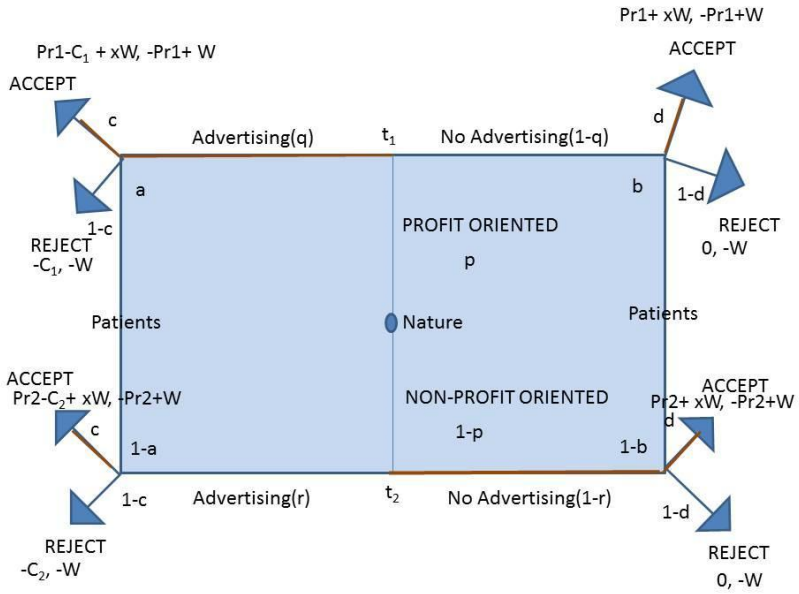


**Figure 45- Separating Equilibrium (Advertising (Profit Oriented) –Non-Advertising (Non Profit-Oriented)**

We see from the above Figure 45 that for advertising scenario, since a=1, we see that the payoffs of the patient are –Pr1+W and –Pr2+W, which are represented by the upper node. For the patient to accept the service which is what the service provider needs to achieve a positive payoff, we have

$$-\Pr 1+W > -W$$

Or Pr1< 2W

Similarly

Pr2 < 2W

Similarly, for non-advertising scenario, we have

Pr1<2W

and Pr2 < 2W

We now have the patient's response which is the uninformed player's optimal response. So if the profit-oriented service provider announces an advertising announcement, the profit-oriented service provider can anticipate that the patient would accept the service if the payoff for the profit-oriented player is:

Pr1- C1 + xW and similarly for the non-advertising scenario, the pay-off is Pr1 + xW.

We see that the profit-oriented service provider can deviate from prescribed strategy.

Similarly, for the non-advertising scenario, we see that Pr2 + xW is greater than Pr2- c2+xW and it will not deviate from prescribed strategy.

Hence, No PBE as strong type deviates in the current condition.

2) Consider the following separating strategy, when SP is profit-oriented firm and does not advertise; and as well as SP is non-profit-based firm and advertises.

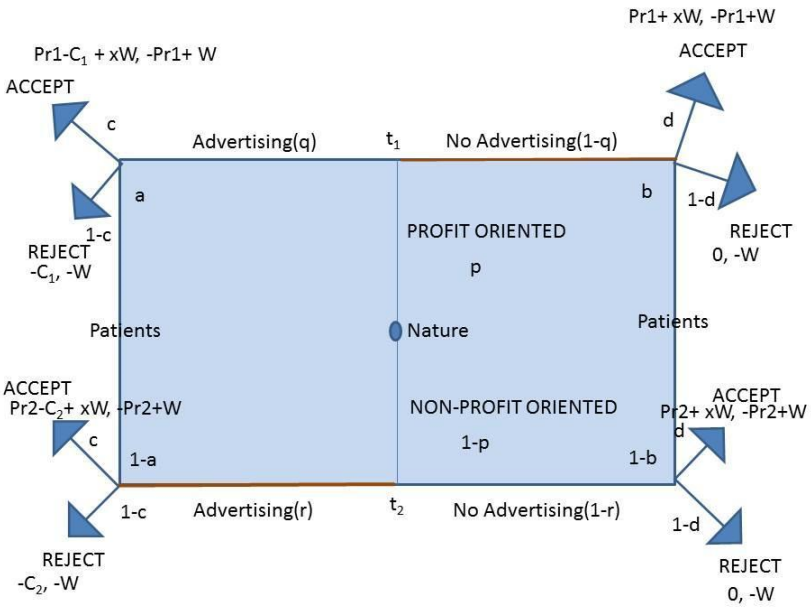


**Figure 46 - Separating Equilibrium (Advertising (Non-Profit Oriented) –Non-Advertising (Profit-Oriented)**

The patient after observing the service provider's type can form and update their beliefs about the service provider, as shown in Figure 46.

Applying Bayes rule to the above situation, which is a separating strategy profile i.e., advertising and non-advertising for the informed player i.e., the service provider:

Here, b= 1 because we apply Bayes Rule

$$b = \frac{p*(1-q)}{p*(1-q)+(1-p)*(1-r)}$$ and for the above separating strategy profile q=0, r=1and

a =0 because

$a = \frac{p*q}{p*q+(1-p)*r}$ and for this, we substitute q=0, r=1. Intuitively, it indicates that when the patient observes no advertising type, it assign zero probability originating from the profit-oriented service provider. When the patient observes the advertising type, it assigns a probability of 1 from the non-profit oriented type.

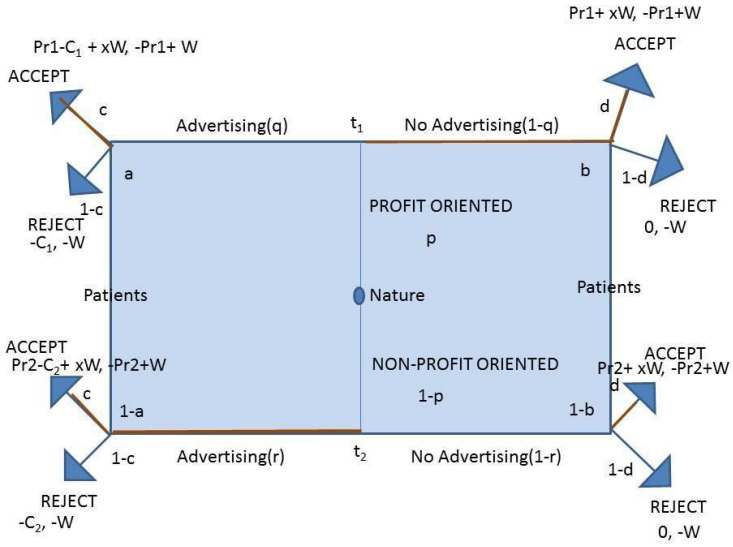


**Figure 47- Separating Equilibrium (Advertising (Non-Profit-Oriented) –Non-Advertising (Profit-Oriented)**

We see from Figure 47 that for non-advertising scenario, since b=0, the payoffs of the patient are –Pr1+W and –Pr2+W, which are represented by the upper node. For the patient to accept the service which is what the service provider needs to achieve a positive payoff, we have

$$-\Pr 1 + W > -W$$

Or Pr1< 2W

Similarly

Pr2 < 2W

Similarly for advertising scenario, we have

Pr1<2W

and Pr2 < 2W

For the patient who is the uninformed player's optimal response, if the profit-oriented service provider announces a non-advertising announcement, it can be anticipated that the patient would accept the service if the payoff for the profit-oriented player is Pr1 + xW . Similarly, for the non-advertising scenario, the pay-off is Pr1-C1 + xW.

We see that it cannot deviate from the prescribed strategy.

Similarly, for the advertising scenario, we see that Pr2 – C2 + xW is lesser than Pr2 +xW and it will deviate from the prescribed strategy.

Hence, there is no PBE as non-profit type deviates in the current situation.

**Proposition 1**

SP can accept the patient's request to serve if there are no costs for advertising.

**Proof**

As there is no separating equilibrium occurs in both the cases, which means that the SP (either Non-Government or Profit-Based Corporate) cannot operate. So, if c1=0 or c2 =0 i.e., and if there is cost-free advertising for either the profit-oriented SP or the non-government SP, there

would be a separating equilibrium in either of the cases and, hence, it will create an opportunity for the SP for the patient's service fulfillment.

### 8.5.2 Pooling Equilibrium

1) Considering the pooling strategy in Figure 48, when the SP is either a profit-oriented firm, or SP is non–profit firm and both advertise:

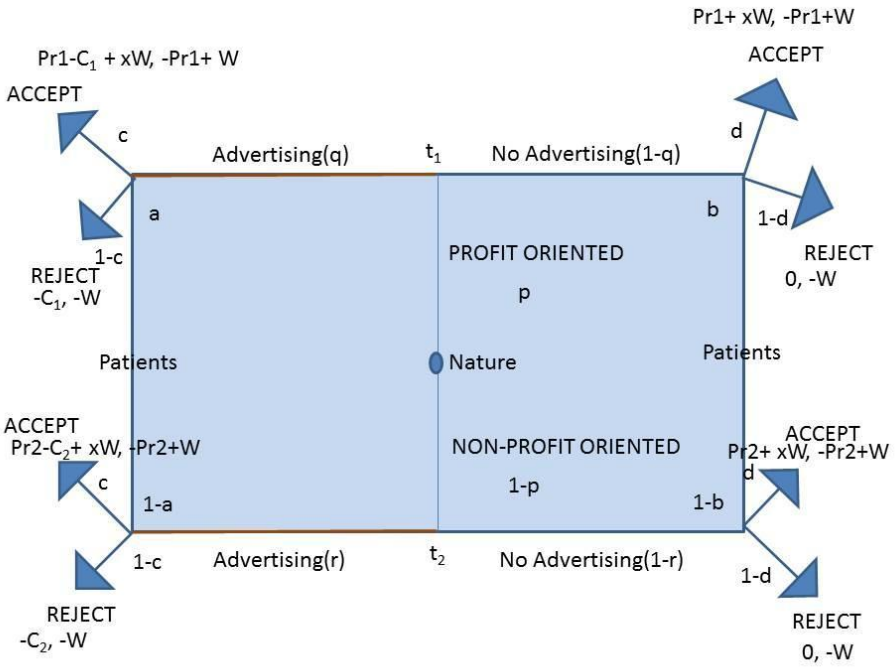


**Figure 48- Pooling Equilibrium (Advertising)**

Using the Bayes rule

$$a = \frac{p*q}{p*q+(1-p)*r}$$

similarly

$$b = \frac{p*(1-q)}{p*(1-q)+(1-p)*(1-r)}$$

As q=r=1

so a= p, b= indeterminate =0/0

Intuitively, since both types of service providers select advertising strategy as announcement in this strategy, the profile of the patient's observation of the advertising strategy does not restrict their posterior beliefs about the service provider type. Therefore, the announcement becomes of no information, thereby, making posterior beliefs, which are updated using Bayes rule, to coincide with prior probability distribution.

In case the patient observes no advertising, they must still update b, but such an announcement occurs off the equilibrium path according to this strategy profile. We can also check this using Bayes rule, as we obtain an indeterminate result.

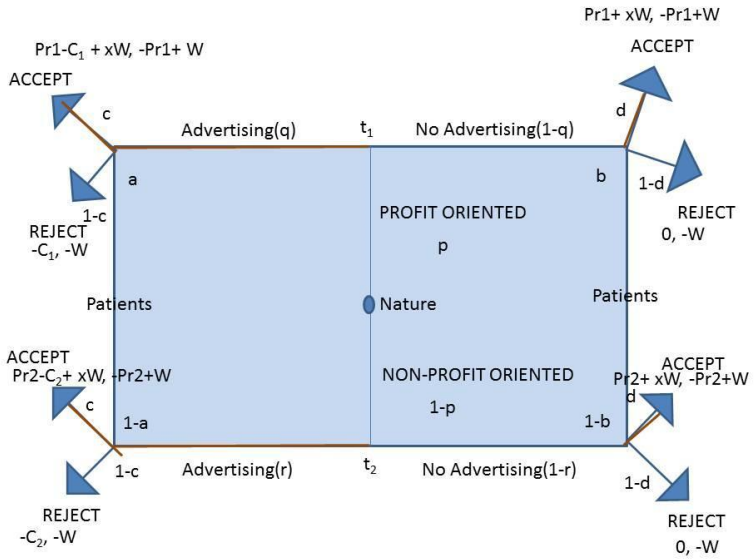


**Figure 49- Pooling Equilibrium-1 (Advertising)**

Given that the advertising announcement, since the beliefs along the equilibrium path satisfy =p, for patients to accept the service when advertising, we have

$$\Pr(A \mid adv) = p*[-\Pr 1 + W] + (1-p)*[-\Pr 2 + W]$$

$$\Pr(R \mid adv) = p*(-W) + (1-p)*(-W)$$

Which gives

$$p > \frac{2*W - \Pr 2}{\Pr 1 - \Pr 2}$$

Upon observing no advertising, since the off-equilibrium beliefs satisfy $b \in (0,1)$, the patients cannot focus on a single node i.e. accept or reject the service.

$$P(A \mid NoAd) = b*(-\Pr 1 + W) + (1-b)*(-\Pr 2 + W)$$

$$P(R \mid NoAd) = b*W + (1-b)*(-W)$$

Patients would accept the service

1) $$b > \frac{2W - \Pr 2}{\Pr 1 - \Pr 2}$$

For this off-the-equilibrium case, we see there is no pooling equilibrium since both informed type deviates from the current strategy profile, unless C1= C2 =0, which is similar to the case that occurred in separating equilibrium

or

Patients would reject the service if

2) $$b \le \frac{2W - \Pr 2}{\Pr 1 - \Pr 2}$$

For this off-the-equilibrium case, the pooling equilibrium exists as both the informed types of SP, profit-oriented or non-profit oriented SP, do not deviate from the current strategy profile for the following conditions

If Pr1+xW > C1

And if Pr2+xW > C2

Therefore, pooling strategy can be supported as an equilibrium when the off equilibrium satisfies the above conditions.

**Proposition 2:** Advertising would lead to positive payoffs for the SP if the costs of advertising follow the given condition.

C2<C1< 2W + xW

**Proof**

If the well-being is W

And if 2W> Pr1(Price of Profit SP) > Pr2 (Price of Non-Profit SP)

We see that $\frac{2W - \Pr 2}{\Pr 1 - \Pr 2} < 1$

Pr2+xW < Pr1+xW< 2W+xW which implies that for

$$b \leq \frac{2W - \Pr 2}{\Pr 1 - \Pr 2}$$

C2<C1< 2W + xW

The above proposition can be applied when the SP feels that non-advertising of their services would lead to the rejection of their services by the patients.

2) When SP is profit-oriented firm or a non-profit-based firm and does not advertise.

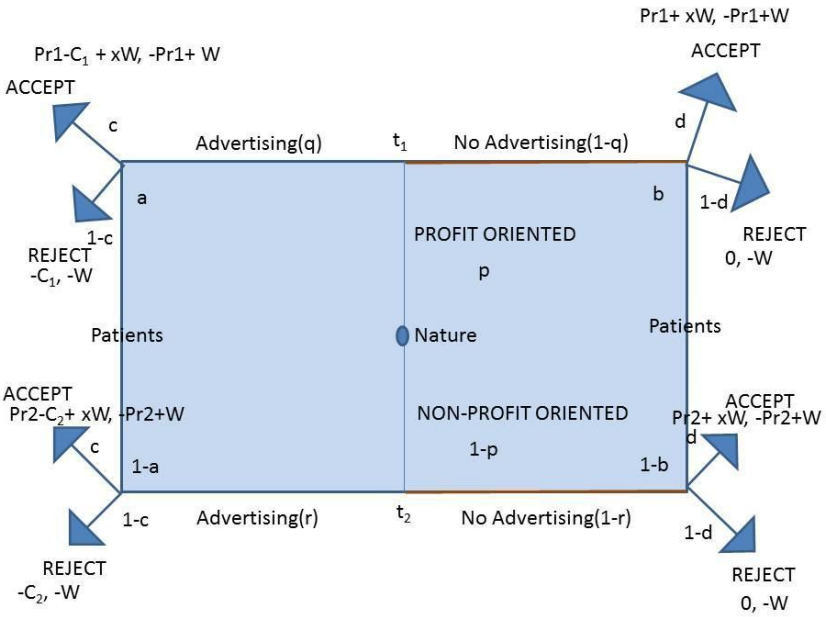


**Figure 50- Pooling Equilibrium (Non-Advertising)**

Using the Bayes rule

$$b = \frac{(1-q)*p}{(1-q)*p+(1-r)*p}$$

$$a = \frac{q*p}{q*p+r*(1-p)}$$

Here, q=0, r=1

b =p, a=0.

Intuitively, since both types of service providers select no advertising strategy as announcement in this strategy profile, the patient's observation of an advertising strategy does not restrict its posterior beliefs about the service provider type. Therefore, the announcement becomes of no information, thereby, making posterior beliefs updated using the Bayes rule coincide with the prior probability distribution.

In case, the patient observes an advertising announcement, they must still update b and a but such an announcement occurs off-the-equilibrium path according to this strategy profile. We can

also check this using the Bayes rule as we obtain an indeterminate result. And this player's beliefs can be arbitrarily specified. i.e., $a \in 1$.

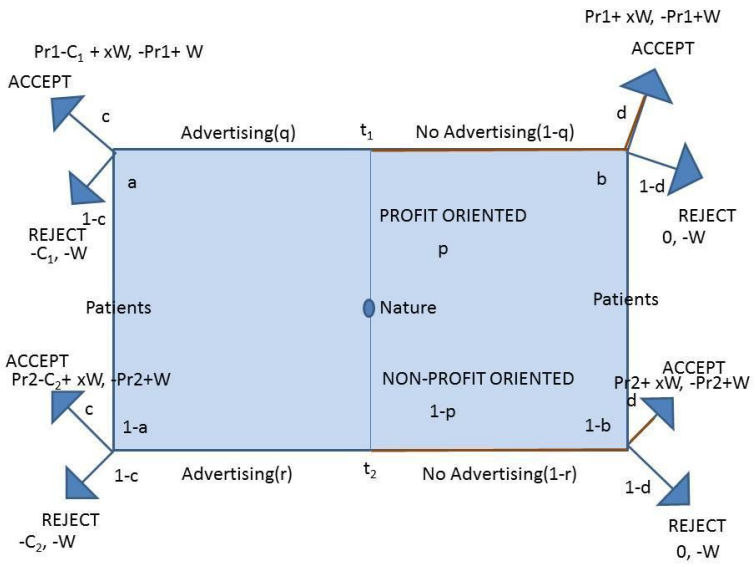


**Figure 51- Pooling Equilibrium**

Given the above condition, the optimal response of the informed player, i.e., the Service Provider

$$\Pr(A \mid Noad) = p*[-\Pr 1 + W] + (1-p)*[-\Pr 2 + W]$$

$$\Pr(R \mid Noad) = p*(-W) + (1-p)*(-W)$$

$$p > \frac{2W - \Pr 2}{\Pr 2 - \Pr 1}$$

Upon observing no advertising, since the off-equilibrium beliefs satisfy $b \in (0,1)$, the patients cannot focus on a single node i.e. accept or reject the service.

$$\Pr(A \mid adv) = p*[-\Pr 1 + W] + (1-p)*[-\Pr 2 + W]$$

$$P(R \mid adv) = b*W + (1-b)*(-W)$$

Upon observing that advertising patients would accept the service if

1) $a > \frac{2W - \Pr 2}{\Pr 1 - \Pr 2}$ or

Patients would reject the service if

2) $a \leq \frac{2W - \Pr 2}{\Pr 1 - \Pr 2}$

We observe that there is pooling equilibrium in both the cases as the strategy profile does not deviate from the current one.

**Proposition 3:** Due to the presence of pooling equilibrium, either type of SPs need not spend on advertising if the patients require their service and the following condition is satisfied.

$$p > \frac{2W - \Pr 2}{\Pr 2 - \Pr 1}$$

**Proof**

Follows from above.

Further, we see that for the above study, no semi-separating equilibrium exists.

### 8.6 Managerial Insights and Conclusions.

No advertising strategy can positively impact a patient's decision to accept or reject the services provided by the SP if they do not reveal their type to the patients.

This can happen in situations like a pandemic where the demand for emergency services increases to a large extent and the government may want to provide equal opportunity of service to both types of service providers, though it may not want to reveal the type of SP involved in the PPP contract to the citizens.

Further, in normal situations when patients require emergency services the advertisement strategy may come to their aid in deciding which service to opt for. Further, as advertisements impact a patient's decision to accept the service in a separating strategy profile, the government may prefer either of the SPs (Profit-Oriented or Non-Profit Oriented) who provides better

payoffs in the PPP contractual relationship integrated along with insurance schemes provided by Yeshaswini or Aarogyasri for both profit as well as non-profit server providers.

# 9 POLICY IMPLICATIONS

As previously shown, each scenario has distinct equilibrium conditions that can guide in the formulation of government policy for the principal-agent games. All scenarios demonstrate that the payoffs of the government and the service provider have a linear upward sloping relation, implying that the government should formulate policies culminating in investments in insurance companies that will provide emergency health services insurance to the citizens This would lead to less "out of pocket payments" for citizens using emergency health care services, which can be quite expensive in emerging economies like India. Further, it should also provide incentives to service providers on the attainment of demand /service realization. Alternatively, the government should also formulate policies to penalize service providers when they decrease their efforts with an increase in investment, as is the case in a few scenarios. The government should also consider suitable policies to aid external finance from private finance initiative (PFI), i.e., the investor. This can aid in increasing the share for the investor, which can lead to further reinvestment. While federal governments in emerging economies like India have come up with insurance schemes over the past few years, there is now need for greater coordination with various states for PPP-based contracts for emergency health services with insurance companies. Further case studies of Yeshashwani as well as Aarogyasri infer that, integrating the insurance schemes provided by the centre along with the states along with infrastructure of EMS is the most viable solution for a PPP contract which faces renegotiation problems with government. This will help in developing socially viable schemes that will reduce the '" out of pocket" expenses for needy individuals specifically during crisis (For Ex, surge of COVID cases during 2020-2021) which India is undergoing, thus improving citizen welfare.

# 10 SUMMARY AND CONCLUSIONS

One of the main reasons for the use of PPP, as opposed to traditional service procurement, is that it can be used to finance, and as well as procure infrastructure and labor to obtain long-term gain in efficiency and effectiveness. Through the principal-agent lens, we have modelled and derived optimal solutions using backward induction. Post-COVID 19 research indicates that the government investment in emergency service providers based on PPP framework has yielded mixed returns as compared to government emergency health systems (Nandi et al 2020). While many problems with the agency relationships are apparent in the scenarios, one of the critical assumptions is that the service provider (agent), be it a corporation or an NGO, is not very keen in pursuing only financial benefit, as is in the case of the emergency health services case. Given that this is a humanitarian service, the service providers/entrepreneurs who consider bidding should keep this in mind. Also, in this study, we have developed policies for different scenarios, when the government has the characteristics of a Stackelberg leader, and the agents are the followers. Further, the equilibrium that we arrive at in each of the scenarios, though based on the general equilibrium theory, is the Stackelberg equilibrium since, in all the scenarios, the service provider acts as the agent, i.e., the follower and the government acts as the leader.

Moreover, the scenarios with renegotiation by service providers show that the government's decision to renegotiate with the service provider (profit or non-profit) primarily depends on the region of elasticity, which is smaller for corporate service providers than non-profits. Similarly, when the investor decides to invest in a non-profit service provider, resulting from government intervention, they invest based on the region of elasticity, which is much larger than when the contract is signed if there is only renegotiation with government. This implies that the investor has much higher probability of executing the contract when renegotiation between the service provider and government fails. Further, we also see that favorable policies can be drawn when Private Finance Initiative, i.e. investors come into play since the government's payoff's tend to increase more steeply than when it is investing alone for the contractual life cycle. In this work, we have developed the models with specific details for emergency health services

projects, with various players, i.e., service -providers (profit-based), NGOs, commercial contractors, government agencies, clients and policymakers. The model is also relevant for other similar PPP projects. We have assumed that there is an information asymmetry between the principal and agent, potentially making the agent more opportunistic in its actions. This can be avoided through suitable negotiations and policy formulations by the government and service providers, or between the private investor and the NGO or other funding agency. One of the limitations of this study is that the findings are pertinent to emergency medical services and future research could apply the framework to other cases, and also explore more scenarios and various other hypotheses. We showed from our study that the models provide less evidence in formulating policy when funding from the government is critical. Yet, there is still enough support and empirical implications that suggest that appropriate policy could be developed through the insights that our work has provided, with future directions in securing good overall health index.

## 11. FUTURE ASPECTS OF FUNDING EMS IN INDIA

Financing service providers for emergency situations is a key factor that must be considered by policymakers in the Indian Government, which includes NITI Aayog (National Institution for Transforming India**)** and other private agencies. Despite the government hospitals across various states having their own ambulance services, there is need to augment services through private operators (both Profit and Non-Profit Service Providers) through PPP that has been a viable solution in the past, as seen from this study. However, India needs a mix of centralization and decentralization bodies to provide guidelines for training and operation of Emergency Medical Services (EMS). The funding of private service providers through PPP has been explored in detail in this study. Some meaningful assertions from the study indicate that the management of the contract model would aid both the government and private service provider in providing effective EMS to the Indian citizens that would improve the overall health index in the country.

## REFERENCES


1. Agheon Phillippe et al. (2000). Agency Costs, Firm Behavior and the Nature of Competition. https://doi.org/10.1016/j.rie.2017.04.005.

2. Akintoye A, Beck M, and Kumaraswamy, M (2016) Public Private Partnership: A Global Review (Edt) Routledge, London, ISBN 978-04-415-72896-
https://doi.org/10.4324/9781315686516

3. Alonso-Conde, A. B., Brown, C., & Rojo-Suarez, J. (2007). Public-private partnerships: Incentives, risk transfer, and real options. *Review of Financial Economics*, *16*(4), 335–349. https://doi.org/10.1016/j.rfe.2007.03.002

4. Auriol, E., & Picard, P. M. (2013). A theory of BOT concession contracts. *Journal of Economic Behavior & Organization*, *89*, 187-209. https://doi.org/10.1016/j.jebo.2011.10.003.

5. Bagwell.K., and G. Ramey (1990). "Advertising and pricing to deter or accommodate entry when the demand is unknown." *International Journal of Industrial Organization*,.93-113. https://doi.org/10.1016/0167-7187(89)90036-2.

6. Baojun Jiang, Jian Ni and Kannan Srinivasan.(2014) " Signaling Through Pricing by Service Providers with social preferences" *Marketing Science.* https://doi.org/ 10.1287/mksc.2014.0850.

7. Baru, R. V. (2003). Privatisation of Health Services: A South Asian Perspective. *Economic and Political Weekly*, *38*(42), 4433–4437. Accessed from http://www.jstor.org/stable/4414156

8. Bennett, S. and Mills, A.(1998), 'Government capacity to contract: health sector experience and lessons,' *Public Administration and Development, vol. 18, no. 4, pp. 307-326.* https://doi.org/10.1002/(SICI)1099-162X(1998100)18:4<307::AID-PAD24>3.0.CO;2-D

9. Michael Bergman & Jan-Erik Lane. (1990). Public Policy in a Principal-Agent Framework, *Journal of Theoretical Politics*, vol. 2(3), pages 339-352. Accessed from https://ideas.repec.org/a/sae/jothpo/v2y1990i3p339-352.html.

10. Besley, T., & Ghatak, M. (2017). Public-private partnerships for the provision of public goods: Theory and an application to NGOs. *Research in Economics*, *71*(2), 356–371. https://doi.org/10.1016/j.rie.2017.04.005.

11. Blanken, A., & Dewulf, G. (n.d.). PPPs in Health: Static or Dynamic? *The Australian Journal of Public Administration*, *69*(S1), 35–47. http://doi.org/10.29145/jmr.72.070204

12. Buso, M. (2019). Bundling versus unbundling: asymmetric information on information externalities. *Journal of Economics, 128*(1), 1-25. https://doi.org/10.1007/s00712-018-0642-0

13. Carr, B. G., Caplan, J. M., Pryor, J. P., & Branas, C. C. (2006). A Meta-Analysis of Prehospital Care Times for Trauma. *Prehospital Emergency Care*, *10*(2), 198–206. https://doi.org/10.1080/10903120500541324

14. Casady, Carter B., Kent Eriksson, Raymond E. Levitt, and W. Richard Scott. 2020. "(Re)Defining Public-Private Partnerships (PPPs) in the New Public Governance (NPG) Paradigm: An Institutional Maturity Perspective." Public Management Review 22, no. 2: 161-183. http:// doi:10.1080/14719037.2019.1577909

15. CHO, I. and D.Kreps (1987) Signaling games and stable equilibrium. Quarterly Journal of Economics 102, 179-222. http://dx.doi.org/10.2307/1913604

16. Chou, J.-S., Ping Tserng, H., Lin, C., & Yeh, C.-P. (2012). Critical factors and risk allocation for PPP policy: Comparison between HSR and general infrastructure projects. *Transport Policy*, *22*, 36–48. https://doi.org/10.1016/J.TRANPOL.2012.05.009.

17. Cobb, Barry and Bawsuchoudhary, Atin.(2009) " A Decision Analysis Approach to Solving the Signaling Game." https://doi.org/10.1287/deca.1090.0148.

18. Chung, C. (2001). The Evolution of Emergency Medicine. *Hong Kong Journal of Emergency Medicine*, *8*(2), 84–89. https://doi.org/10.1177/102490790100800204.

19. Cooley, Thomas F. and Bruce D. Smith (1987). Equilibrium in Cooperative Games of Policy Formulation. Working Paper No. 84, Rochester Centre of Economic Research. Accessed from https://rcer.econ.rochester.edu/RCERPAPERS/rcer_84.pdf

20. David, S. S., Vasnaik, M., & TV, R. (2007). Emergency medicine in India: Why are we unable to walk the talk *Emergency Medicine Australasia*, *19*(4), 289–295. https://doi.org/10.1111/j.1742-6723.2007.00985.x

21. Baxter D, Casady CB. Proactive and Strategic Healthcare Public-Private Partnerships (PPPs) in the Coronavirus (Covid-19) Epoch. *Sustainability*. 2020; 12(12):5097. https://doi.org/10.3390/su1212509.

22. De Bettignies, J.-E., & Ross, T. W. (2004). The Economics of Public-Private Partnerships. *Canadian Public Policy / Analyse de Politiques*, *30*(2), 135–154. https://doi.org/10.2307/3552389

23. De Brux, J. (2010). The Dark and Bright Sides of Renegotiation: An Application to Transport Concession Contracts. *Utilities Policy*, *18*(2), 77–85. https://doi.org/10.1016/j.jup.2009.07.003

24. Mehta, Anouj; Bhatia, Aparna; Chatterjee, Ameeta. 2010. *Improving Health and Education Service Delivery in India through Public-Private Partnerships*. © Asian Development Bank. Accessed from http://hdl.handle.net/11540/1036.

25. Dykstra, E. H. (1997). International models for the practice of emergency care. *The American Journal of Emergency Medicine*, *15*(2), 208–209. Accessed from https://doi.org/10.1016/S0735-6757(97)90107-8

26. Elitzur, R., & Gavious, A. (2003). Contracting, signaling, and moral hazard: a model of entrepreneurs, 'angels,' and venture capitalists. *Journal of Business Venturing*, *18*(6), 709–725. https://doi.org/10.1016/S0883-9026(03)00027-2

27. Elitzur, R., & Gavious, A. (2011). Selection of entrepreneurs in the venture capital industry: An asymptotic analysis. https://doi.org/10.1016/j.ejor.2011.06.029.

28. Case Study on “Emergency Medical Service (EMS) in India: A Concept Paper” by National Health Systems Resource Centre (NHSRC) Technical Support Institution with National Rural Health Mission (NRHM) Ministry of Health & Family Welfare, Government of India. Accessed from https://fdocuments.in/document/ems-concept-paper.html.

29. *Sulakshana Nandi, Vandana Prasad, Deepika Joshi, Indira Chakravarthi, Ganapathy Murugan, Shahnawaz Khan, Mohammed Allam Ashraf, Pallavi Gupta, Chandan Kumar*. (2021). *Public Private Partnerships in healthcare, Evidence from India.* Accessed from https://epw.in/journal/2021/36/perspectives/public-private-partnerships-healthcare.html

30. Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, *70*(1), 99–126. https://doi.org/10.1016/0304-4076(69)41685-7.

31. Grimsey, D., & Lewis, M. (2007). Public Private Partnerships and Public Procurement. *Agenda: A Journal of Policy Analysis and Reform*, *14*(2), 171–188..https://doi.org/10.22459/AG.14.02.2007.06

32. Gupta, M. Das, & Rani, M. (2004). *India's Public Health System: How Well Does It Function at the National Level?* The World Bank. https://doi.org/10.1596/1813-9450-3447.

33. Felix Munoz-Garcia (2012). "A systematic procedure for finding perfect equilibria in Incomplete Information Games" vol. 6, no. 1, 2012, pp. https://doi.org/10.1515/1935-5041.1049

34. Frank A Sloan & Chee Ruey Hsieh (2017) Health economics. The MIT Press Jan 27, 2017 | 840 Pages | 8 x 9 | ISBN 9780262035118.

35. Fudenbeg, D., J.Tirole. 1993. Game Theory. MIT Press. Cambridge . MA.

36. Gibbons, R.1992 Game Theory For economists. Princeton University Press, Princeton, NJ.

37. Hart, O. (2003). Incomplete Contracts and Public Ownership: Remarks, and an Application to Public-Private Partnerships. *The Economic Journal*, *113*(486), C69–C76. https://doi.org/10.1111/1468-0297.00119

38. Hayllar, M. R., & Wettenhall, R. (2010). Public-Private Partnerships: Promises, Politics, and Pitfalls. *The Australian Journal of Public Administration*, *69*(S1), 1–7. https://doi.org/10.1111/j.1467-8500.2009.00657.x

39. Ho, S. P. (2009). Government Policy on PPP Financial Issues: Bid Compensation and Financial Renegotiation. *Policy, Finance & Management for Public-Private Partnerships*, 267–300. https://doi.org/10.1002/9781444301427.ch15

40. Ho, Thomas S. Y. and Lee, Sang Bin, (2004), The Oxford Guide to Financial Modeling: Applications for Capital Markets, Corporate Finance, Risk Management and Financial Institutions, Oxford University Press. Accessed from https://EconPapers.repec.org/RePEc:oxp:obooks:9780195169621.

*41.* Huige Xing 1, Yuelin Li 1 and Hongyang Li 2,3, (2020). Renegotiation Strategy of Public-Private Partnership Projects with Asymmetric Information— An Evolutionary Game Approach. *Sustainability*, https://doi.org/10.3390/su12072646

42. Hung, K. K. C., Cheung, C. S. K., Rainer, T. H., & Graham, C. A. (2009). International EMS systems: China. *Resuscitation*, *80*, 732–735. https://doi.org/10.1016/j.resuscitation.2009.04.016.

43. Kennedy, G. M. (2013). Can game theory be used to address PPP renegotiations ? A retrospective study of the of the Metronet - London Underground PPP By Dissertation submitted in partial fulfillment of requirements for the degree of MSc in Business Administration, at the Univers, (June). Accessed from http://hdl.handle.net/10400.14/15839

44. Klijn, E. H., & Koppenjan, J. (2016). Public Money & Management The impact of contract characteristics on the performance of public-private partnerships (PPPs). https://doi.org/10.1080/09540962.2016.1206756.

45. KPMG. (2015). *The Emerging Role of PPP in Indian Healthcare Sector Prepared By In collaboration with the Indian government*. [White Paper], Accessed from https://www.ibef.org/download/PolicyPaper.pdf

46. Kuruvilla, Sarosh & Liu, Mingwei & Jacob, Priti. (2005). A Case Study of the Yeshasvini Health Insurance Scheme for the Rural Poor in India. International Journal of Self Help and Self Care. 3. 261-306. 10.2190/D60U-5637-M315-3K57.

47. Liu, X., Hotchkiss, D. R., & Bose, S. (2007). The impact of contracting-out on health system performance: A conceptual framework. *Health Policy*, *82*, 200–211. https://doi.org/10.1016/j.healthpol.2006.09.012

48. Lv, J., Ye, G., Liu, W., Shen, L., & Wang, H. (2015). Alternative Model for Determining the Optimal Concession Period in Managing BOT Transportation Projects. *Journal of Management in Engineering*, *31*(4), 04014066. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000291.

49. Madhurima Nundy and Rama V Baru. (2013). Private Partnerships of Boundaries: Public-Blurring in Health Services in India. *Economic Political Weekly*, *43*(4), 62–71. Accessed from https://www.epw.in/journal/2008/04

50. MacAl, C. M., & North, M. J. (2010). Tutorial on agent-based modeling and simulation. *Journal of Simulation*, *4*(3), 151–162. Accessed from https://doi.org/10.1057/jos.2010.3

51. Manigart, S., De Waele, K., Wright, M., Robbie, K., Desbrières, P., Sapienza, H. J., & Beekman, A. (2002). Determinants of required return in venture capital investments: a five-country study. *Journal of Business Venturing*, *17*(4), 291–312. https://doi.org/10.1016/S0883-9026(00)00067-7

52. Mason, C. M., & Harrison, R. T. (2002). Is it worth it? The rates of return from informal venture capital investments. *Journal of Business Venturing*, *17*(3), 211–236. https://doi.org/10.1016/S0883-9026(00)00060-4

53. Medda, F. R., Carbonaro, G., & Davis, S. L. (2013). Public-private partnerships in transportation: Some insights from the European experience. *IATSS Research*, *36*(2), 83–87. https://doi.org/10.1016/J.IATSSR.2012.11.002

54. Mitroff, I. I., & Mason, R. O. (2011). The Metaphysics of Policy and Planning: A Reply to Cosier. *Academy of Management Review*, *6*(4), 649–651. https://doi.org/10.5465/amr.1981.4285721

55. Sethi, Nitin & Rao, Menaka. (2017) NITI Aayog and health ministry prepare model contract for privatizing urban health care. *Scroll.in.* Accessed from https://scroll.in/pulse/844272/niti-aayog-and-health-ministry-prepare-model-contract-for-privatising-urban-health-care

56. Oliveira Cruz, C., & Cunha Marques, R. (2014). Theoretical Considerations on Quantitative PPP Viability Analysis. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000184

57. Prakash, G., & Singh, A. (2010). *A New Public Management Perspective in Indian E-Governance Initiatives*. Accessed from https://www.csi-sigegov.org/critical_pdf/8_71-80.pdf

58. Raman, A. V., Björkman, J. W., & Björkman, J. W. (2008). *Public-Private Partnerships in Health Care in India*. Routledge. https://doi.org/10.4324/9780203886557

59. Roberts, M. J., Hsiao, W., Berman, P., & Reich, M. R. (2008.). Getting Health Reform Right. https://doi.org/10.1093/acprof:oso/9780195371505.001.0001.

60. Ross, T. W., & Yan, J. (2015). Journal of Comparative Policy Analysis: Research and Practice Comparing Public-Private Partnerships and Traditional Public Procurement: Efficiency vs. Flexibility. *Journal of Comparative Policy Analysis: Research and Practice*, *17*(5), 448–466. https://doi.org/10.1080/13876988.2015.1029333

61. Schneider, S. M., Gardner, A. F., Weiss, L. D., Wood, J. P., Ybarra, M., Beck, D. M.,Jouriles, N. J. (2010). The Future of Emergency Medicine. *The Journal of Emergency Medicine*, *39*(2), 210–215. https://doi.org/10.1016/J.JEMERMED.2010.06.001

62. Serra, Danila & Serneels, Pieter & Barr, Abigail,(2010)."Intrinsic Motivations and the Non-Profit Health Sector: Evidence from Ethiopia," IZA Discussion Papers 4746, Institute of Labor Economics. Accessed from https://ideas.repec.org/p/iza/izadps/dp4746.html.

63. Shi, L., Zhang, L., Onishi, M., Kobayashi, K., & Dai, D. (2018). Contractual Efficiency of PPP Infrastructure Projects: An Incomplete Contract Model. *Mathematical Problems in Engineering*, *2018*, 1–13. https://doi.org/10.1155/2018/3631270

64. Singh, A., & Prakash, G. (2010). Public-Private Partnerships in Health Services Delivery. *Public Management Review*, *12*(6), 829–856. https://doi.org/10.1080/14719037.2010.488860

65. Spence. M (1973) “Job Market Signaling” Quarterly Journal of Economics 87, pp 355-371. https://doi.org/10.2307/1882010

66. Sharma M, Brandler ES (2014). Emergency medical services in India: the present and future. Prehosp Disaster Med. 2014;29(3):307-310. https://doi:10.1017/S1049023X14000296

67. Subhan, I., & Jain, A. (2010). Emergency care in India: the building blocks. *International Journal of Emergency Medicine*, *3*(4), 207–211. https://doi.org/10.1007/s12245-010-0223-7

**68.** Titoria, R., & Mohandas, A. (2019). A glance on public-private partnership: an opportunity for developing nations to achieve universal health coverage. *International Journal Of Community Medicine And Public Health*, *6*(3), 1353. https://doi.org/10.18203/2394-6040.ijcmph20190640

**69.** Tserng, H. P., Russell, J. S., Hsu, C. W., & Lin, C. (2012). Analyzing the role of national PPP units in promoting PPPs: Using new institutional economics and a case study. *Journal of construction engineering and management*, *138*(2), 242-249. http://doi.org/10.1061/(ASCE)CO.1943-7862.0000398

70. Ho, T.S.Y & Lee, S.B. (2004). The Oxford Guide to Financial Modelling: Applications for Capital Markets, Corporate Finance, Risk Management and Financial Institutions. OUP Publishers, USA. https://doi.org/10.2469/faj.v62.n2.4088.

71. Vasudevan, V., Singh, P., & Basu, S. (2016). Importance of awareness in improving performance of emergency medical services (EMS) systems in enhancing traffic safety: A lesson from India. *Traffic Injury Prevention*, *17*(7), 699–704. https://doi.org/10.1080/15389588.2016.1163689

72. Venkitasubramanian, Akshay, (2010). A Study of PPP Models for Social Healthcare Insurance. Centre for public policy research. Accessed from https://www.cppr.in/wpcontent/uploads/2012/03/A-Study-of-PPP-Models-for-Social-Healthcare-Insurance-Akshay-V.pdf

73. Wibowo, A., & Alfen, H. W. (2015a). Critical success factors in public-private partnership (PPP) on infrastructure delivery in Nigeria. *Asia-Pacific Journal of Business Administration*, *5*(1), 212–225. https://doi.org/10.1108/BEPAM-03-2014-0016

74. Wibowo, A., & Alfen, H. W. (2015b). Government-led critical success factors in PPP infrastructure development. *Built Environment Project and Asset Management*, *5*(1), 121–134. https://doi.org/10.1108/BEPAM-03-2014-0016

75. X Guo & B Jiang(2016).Signaling through price and quality to consumers with fairness concerns". *Journal of Marketing Research.* https://doi.org/10.1509/jmr.15.0323

## APPENDIX

**Appendix A.1**

Solving Agent's i.e. the service provider's problem while applying (KKT conditions)

The problem in the standard KKT Format becomes

Maximize $p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} - (p^H * e_H^2)/2$ ----------(A1)

$e^H$

ST

$(p^H * E_H^2)/2 - p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} \le (p^L * e_L^2)/2 - p^L * (1-t) * r * A * e_L^{\alpha_1} * I^{\alpha_2}$ - (A2)

$p^H * e_H^2 / 2 - p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2} \le -\bar{\bar{U}}$ ----------(A3)

The KKT conditions are

$$p^H * (1-t) * r * \alpha_1 * A * e_H^{\alpha_1 - 1} * I^{\alpha_2} - p^H * e_H$$
$$-\lambda_1 * (p^H * e_H - p^H * (1-t) * r * \alpha_1 * A * e_H^{\alpha_1 - 1} * I^{\alpha_2})$$
$$-\lambda_2 * (p^H * e_H - p^H * (1-t) * r * \alpha_1 * A * e_H^{\alpha_1 - 1} * I^{\alpha_2}) = 0 \quad \text{----------} \quad \text{(A4)}$$

$\lambda_1 * [(p^L * e_L^2)/2 - (p^H * e_H^2)/2 + (1-t) * r * A * \{p^H * e_H^{\alpha_1} - p^L * e_L^{\alpha_1}\} * I^{\alpha_2}] = 0$ ---------- (A5)

$\lambda_2 * [-\bar{\bar{U}} - p^H * e_H^2 / 2 + p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{\alpha_2}] = 0$ ---------- (A6)

Case 1

$\lambda_1 = 0, \lambda_2 = 0$

Solving for $e^H$ we have

$$e^H = [(1-t)*r*A*\alpha_1*I^{1-\alpha_1}]^{1/(2-\alpha_1)}$$ ----------(A7)

Case 2

$$\lambda_1 = 0, \lambda_2 > 0.$$

Solving, we obtain $\lambda_2 = -1,$ which is not possible.

Case 3

$$\lambda_1 > 0, \lambda_2 = 0$$

Solving,

$\lambda_1 = -1$, which is not possible.

Case 4

$$\lambda_1 > 0, \lambda_2 > 0$$

This case need not be considered because we have obtained optimal solution in Case 1.

Also we have the second order of the Service Provider's objective function

$$p^H*(1-t)*r*A*\alpha_1*(\alpha_1-1)*e_H^{\alpha_1-2}*I^{\alpha_2}$$ ----------(A8)

The above second order expression is negative as $\alpha_1 \leq 1$

Solving the Principal's i.e. the government's problem, which is an unconstrained optimization problem

$$\underset{I}{Maximize} \quad p^H*t*r*A*e_H^{\alpha_1}*I^{\alpha_2} + k*p^H*A*e_H^{\alpha_1}*I^{\alpha_2} - I(1+\nu)$$ ----------(A9)

Substituting $e^H = [(1-t)*r*A*\alpha_1*I^{1-\alpha_1}]^{1/(2-\alpha_1)}$ in the above equation and inputting

$$p^H * A*[r*A*\alpha_1*(1-t)]^{(\alpha_1/(2-\alpha_1))} = Z$$

We have the objective function as

$$\underset{I}{Maximize}\, Z[t+k]*I^{2*\alpha_2/2-\alpha_1} - I(1+\nu) \quad \text{---------- (A10)}$$

As the above problem is an unconstrained optimization problem, we have from First order conditions

$$\frac{\delta(Z[t+k]*I^{2*\alpha_2/2-\alpha_1} - I(1+\nu))}{\delta I} = 0 \quad \text{---------- (A11)}$$

Taking the second derivative, we have leads to the following maximum

$$\frac{\partial^2((Z[t+k]*I^{2*\alpha_2/2-\alpha_1} - I(1+\nu))}{\partial I^2} = -2*\alpha_1*\alpha_2/(2-\alpha_1)^2 < 0 \quad \text{---------- (A12)}$$

Which means that the objective function has a maximum.

The first order conditions leads to

$$I = \left(\frac{1+\alpha_2}{2*\alpha_2}\right)^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (1-\alpha_2) * \left(\frac{1+\upsilon}{(t*r+k)*(p_H*A)}\right)^{\frac{-(1+\alpha_2)}{(1-\alpha_2)}} * (r*A(1-t)) \quad \text{-------- (A13)}$$

**Proof of Proposition 1**

(A.8) and (A.12) demonstrate that the second order differentials are negative, which means that they are concave, leading in turn, to the existence of equilibrium conditions. Further, we show that only one internal intersection between them can happen, as shown in Figure 2, due to the strict concavity, the other one being zero.

**Proof of Proposition 2**

Figure 2(b) and A7 and A13 show the following

$$e_H = K*(\alpha_1)^{1/(2-\alpha_1)} * I^{(1-\alpha_1)/(2-\alpha_1)}$$

$$\frac{\partial e_H}{\partial \alpha_1} \geq 0$$

and similarly, as $\frac{\partial I}{\partial \alpha_2} \geq 0$ an increase in $\alpha_1$ i.e. decrease in $\alpha_2, e_H$ increases and investment decreases, thus leading to an underinvestment around equilibrium point 2.

**Appendix A.2**

The objective function of the service provider

$$\underset{E^H}{Maximize}\ p^H * \beta * (1-t) * r * A * e_H^{\alpha_1} * I^{*\alpha_2} * e^{-\theta} - (p^H * e_H^2 * (a + b*\theta + c*\theta^2)/2 \quad \text{---------(A14)}$$

And the objective function of the government is given by

$$\underset{\beta, I}{Maximize}\ p^H * t * (1-\beta) * r * A * e_H^{\alpha_1} * I^{*\alpha_2} * e^{-\theta} + k * p^H * A * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta} - I(1+\nu) \quad \text{-------- (A15)}$$

Agent Problem

The KKT conditions are:

$$p^H * \beta * (1-t) * r * A * \alpha_1 * e_H^{\alpha_1 - 1} * I^{*\alpha_2} * e^{-\theta} - (p^H * e_H * (a + b*\theta + c*\theta^2)$$
$$-\lambda_1((p^H * e_H) * (a + b*\theta + c*\theta^2) - p^H * (1-t) * r * \beta * A * \alpha_1 * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta})$$
$$-\lambda_2((p^H * e_H) * (a + b*\theta + c*\theta^2) - p^H * (1-t) * r * \beta * A * \alpha_1 * e_H^{\alpha_1} * I^{*\alpha_2} * \exp^{-\theta}) = 0 \quad \text{---------- (A16)}$$

$$\lambda_1 * [(p^L * e_L^2) * (a + b*\theta + c*\theta^2)/2 - (p^H * e_H^2) * (a + b*\theta + c*\theta^2)/2 +$$
$$(1-t) * r * A * \{p^H * e_H^{\alpha_1} - p^L * e_L^{\alpha_1}\} * I^{*\alpha_2}] = 0 \quad \text{---------- (A17)}$$

$$\lambda_2 * [-\bar{U} - p^H * e_H^2/2 + p^H * (1-t) * r * A * e_H^{\alpha_1} * I^{*\alpha_2}] = 0 \quad \text{---------- (A18)}$$

Case 1

$\lambda_1 = 0, \lambda_2 = 0$

Solving for $e^H$ we have

$e^H = [(1-t)*r*A*\beta*\alpha_1*I^{1-\alpha_1}*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{1/(2-\alpha_1)}$ ----------(A19)

Case 2

$\lambda_1 = 0, \lambda_2 > 0.$

Solving, we obtain $\lambda_2 = -1$ which is not possible.

Case 3

$\lambda_1 > 0, \lambda_2 = 0.$

Solving

$\lambda_1 = -1$

which is not possible.

Case 4

$\lambda_1 > 0, \lambda_2 > 0$

This case need not be considered because we have obtained optimal solution in Case 1.

Principal Problem

Substituting $e^H = [(1-t)*r*A*\beta*\alpha_1*I^{*1-\alpha_1}*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{1/(2-\alpha_1)}$ in the above equation (25) and then putting

$p^H * A*[(1-t)*r*A*\alpha_1*\exp^{-\theta}/(a+b*\theta+c*\theta^2)]^{\alpha_1/(2-\alpha_1)}*\exp^{-\theta} = R$ ---------- (A20)

$$\frac{\partial SP_{payoff}}{\partial e_H} = p^H * \beta * (1-t) * r * A * \alpha_1 * (\alpha_1 - 1) * e_H^{\alpha_1 - 2} * I^{*\alpha_2} * e^{-\theta}$$ ----------(A21)

The objective function of the government becomes

$$\underset{\beta, I}{Maximize}\, t * r * R * [(1-\beta)] * [\beta^{\alpha_1/2-\alpha_1}] * I^{*2\alpha_2/2-\alpha_1} + k * R * [\beta^{\alpha_1/2-\alpha_1}] * I^{*2\alpha_2/2-\alpha_1} - I^{*}(1+\nu)$$ ----- (A22)

Or

$$\underset{I, \beta}{Maximize}(k + (1-\beta) * t * r) * R * \beta^{\frac{\alpha_1}{2-\alpha_1}} * I^{\frac{2*\alpha_2}{2-\alpha_1}}$$ ---------- (A23)

And the second order condition of the government payoff is

$$\frac{\partial^2 Gov_{payoff}}{\partial I^2} = \frac{K * (-2 * \alpha_1 * \alpha_2)}{(2-\alpha_1)^2}$$ ----------(A24)

Using the first-order-condition, $\frac{dF}{d\beta} = 0,$ we obtain value for $\beta = (\alpha_1 / 2 * t * r) * [1+k]$

And

$$\frac{\delta F}{\delta I} = 0, I^{*} = \frac{[k + (1-\beta) * t * r]^{\frac{1+\alpha_2}{1-\alpha_2}} * R^{\frac{1+\alpha_2}{1-\alpha_2}}}{(1+\upsilon)^{\frac{1+\alpha_2}{1-\alpha_2}}}$$

When we have

Where $\beta$ is substituted from prior equation.

For the objective function to be concave, we see that first principal minor is negative and the second principal minor needs to be positive at the stationary point optimal point.

**Proof for Proposition 3**

Similar to proposition 1, the second order differentials (A21) and (A24) are negative for the region $0 \le \alpha_1 \le 0.1,$ which means that they are concave leading to existence of equilibrium conditions. Further, as they are strictly concave functions, they lead to two equilibrium conditions, as shown in Figure 3.

**Proof for Proposition 4**

We know that from first order conditions

$$dSP = p^H * \beta * (1-t) * r * A * e_H^{\alpha_1} * I^{*\alpha_2} * e^{-\theta} - (p^H * e_H^2 * (a + b * \theta + c * \theta^2) / 2$$
$$dSP = d(K' * e_H^{\alpha_1} * I^{*\alpha_2}) - C * e_H de_H$$

From this it follows that the overall function ($dSP$) is decreasing as the first part is constant (for $\alpha_1 + \alpha_2 = 1$) or decreasing ($\alpha_1 + \alpha_2 < 1$) and the second part of the RHS is decreasing.

From the first order conditions of the government, we have

$dGov = C' * I^{\frac{\alpha_1}{\alpha_1 - 2}} * dI$, which is a decreasing function in I.

As both the first order of the payoff functions are decreasing for the conditions we see that, there can be opportunistic behavior by both the government and the service provider i.e. even if they decrease their investment or effort as it may not lower their payoffs.

## Appendix A.3

The Service Provider's objective function is

$$(1-\delta) * (1-t) * p^H * r * A * e_H^{\alpha_1} * I_{vc}{}^{\alpha_2} * \exp^{-\theta} - p^H * e_H^2 * (a + b * \theta + c * \theta^2) / 2 \quad \text{--- (A25)}$$

And the Investor's Objective function is

$$\delta * (1-t) * p^H * r * A * e_H^{\alpha_1} * I_{vc}{}^{\alpha_2} * \exp^{-\theta} - I_{vc}(1+\omega) \quad \text{---------- (A26)}$$

**Proof for Proposition 5**

(A25) and (A26) demonstrate that the second order differentials are negative, meaning they are concave thus, testifying to the presence of equilibrium conditions. Further, only one internal intersection between

them can happen as shown in Figure 4 due to the strict concavity (from the first order they are strictly increasing), the other one being zero.(Refer Figure 4).

**Appendix A.4**

The service provider's and government payoff functions are as given below.

$r * A * e^{\alpha_1} * I^{\alpha_2} - e^2 / 2$ ---------- (A27)

$k*A*e^{\alpha_1} * I^{\alpha_2} - (1+v)*I$ ---------- (A28)

**Proof for Proposition 6**

(A27) and (A28) demonstrate that the second order differentials are negative, thus concave, leading to the existence of equilibrium conditions, as shown in Figure 5.

**Proof for Proposition 7**

The first order for the Non-profit SP and the government respectively are given below.

$$dSP = d(r * A * e^{\alpha_1} * I^{\alpha_2}) - ede$$
$$dI = d(k * A * e^{\alpha_1} * I^{\alpha_2}) - (1+\upsilon)dI$$

The above equations demonstrate that both the functions are decreasing as $d(r*A*e^{\alpha_1} * I^{\alpha_2})$ and $d(k*A*e^{\alpha_1} * I^{\alpha_2})$ are either constant (for $\alpha_1 + \alpha_2 = 1$ ) or decreasing (for $\alpha_1 + \alpha_2 < 1$) hence, the payoffs can increase even when the effort put and the investment decrease around the equilibrium region. Thus, both the government and the service provider could potentially behave opportunistically, i.e. decrease their investment or effort as it may not result in lower payoffs for them.

**Appendix A.5**

$$(1-\Delta)*r*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}-\frac{e^2}{2}*(a+b*\theta+c*\theta^2)$$ ---------- (A29)

Whereas the objective function of the government becomes

$$\Delta*r*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}+k*A*e^{\alpha_1}*I^{*\alpha_2}*\exp^{-\theta}-I^{*}(1+\nu)$$ ---------- (A30)

**Proof of Proposition 8**

From (A29) and (A30), the equations demonstrate that the second order differentials are negative which means that they are concave, testifying to the existence of equilibrium conditions, as shown in Figure 6.

**Proof of Proposition 9**

The first order for the non-profit SP and the government respectively are given below.

$$dSP = d(r*A*e^{\alpha_1}*I^{\alpha_2})-e*(a+b*\theta+c*\theta^2)de$$
$$dI = d(k*A*e^{\alpha_1}*I^{\alpha_2})-(1+\upsilon)dI$$

From the above, the equations demonstrate that both the functions are decreasing as $d(r*A*e^{\alpha_1}*I^{\alpha_2})$ and $d(k*A*e^{\alpha_1}*I^{\alpha_2})$ are either constant (for $\alpha_1+\alpha_2=1$) or decreasing (for $\alpha_1+\alpha_2<1$) hence, the payoffs can increase even when the effort and the investment decrease around the equilibrium region. Thus, both the government and the service provider could potentially behave opportunistically, i.e. decrease their investment or effort as it may not result in lower payoffs for them.

# Appendix 2

| Definition | Author(s) |
|---|---|
| Cooperations of some sort of durability between public and private actors in that they jointly develop products and services and share risks, costs and resources that are connected with these products. | Van Ham & Koppenjan (2001) |
| An arrangement where government states its need for capital-intensive, long-lived infrastructure and the desired facility is built using a complex combination of government and (mostly) private financing and then operated by a private entity under a long-term franchise, contract or lease. | Savas (2000) |
| Working arrangements based on a mutual commitment (over and above the implied in any contract) between a public sector organization with any other organization outside the public sector. | Bovaird (2004) |
| A form of structured cooperation between public and private partners in the planning/construction and/or exploitation of infrastructural facilities in which they share or reallocate risks, costs, benefits, resources, and responsibilities. | Koppenjan (2005) |
| Complex, long-term municipal contracts with private companies for some combination of services, construction, or financing in return for some combination of public funds, public assets, or user fees. | Bloomfield (2006) |
| Arrangements whereby private parties participate in, or provide support for, the provision of infrastructure, and a PPP project results in a contract for a private entity to deliver public infrastructure-based services. | Grimsey & Lewis (2007) |
| A contractual arrangement between a public or governmental agency and a private entity that facilitates greater participation by the private entity in the delivery and operation of an infrastructure project, facility or service. Typically, within the transport sector, such an arrangement involves one or more aspects of the funding, financing, planning, design, construction, operation and maintenance of a transportation facility. Within the commonly utilized context of financing and/or delivering projects, a public-private partnership is an approach or mechanism that is utilized to move the funding process from a single strategy of governmental aid through grants to regional and local authorities, to a more diversified approach involving increased utilization of private capital markets | Schneider & Davis (2007) |
| Contractual arrangements in which certain risks are transferred from public agencies to private firms – as a way to fund these [funding] deficits, accelerate competition, improve operating efficiencies, and reduce operating costs. | Page, Ankner, Jones, & Fetterman (2008) |
| A long-term contractual arrangement between the public and private sectors where mutual benefits are sought and where ultimately (a) the private sector provides management and operating services and/or (b) puts private finance at risk. | Garvin & Bosso (2008) Garvin (2010) |
| A contracting arrangement in which a private party (normally a consortium) is structured around a special purpose vehicle (SPV). | Raisbeck, Duffield, & Xu (2010) |
| Public–private partnerships are ongoing agreements between government and private sector organizations in which the private organization participates in the decision-making and production of a public good or service that has traditionally been provided by the public sector and in which the private sector shares the risk of that production. | Forrer, Kee, Newcomer & Boyer (2010) |
| A cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards. | The Canadian Council for Public-Private Partnership (CCPPP, 2015) |
| PPPs are typically medium to long term arrangements between the public and private sectors whereby some of the service obligations of the public sector are provided by the private sector, with clear agreement on shared objectives for delivery of public infrastructure and/or public services. | Public-Private Partnership In Infrastructure Resource Center (PPPIRC, 2015) |
| Public-private partnerships (P3s) are contractual agreements formed between a public agency and a private sector entity that allow for greater private sector participation in the delivery and financing of transportation projects. | Federal Highway Administration (2015) |

**Table 2: Literature Review of PPP**

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