Case Study : Olmos Diversion Project for Transforming Peru

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Abstract

This project consists of a dam and a tunnel. The main aim of this project was to transport water from Cajamarca region to the Lambayeque region near Olmos. This transported water would make irrigation possible on 1,07,000 acres of arid farmland. The west and east regions of Peru separated by Andes mountains which are 7,000 ft high suffer two different extreme conditions. The west suffers a year long annual drought whereas, the East is flooded for most of the year. The only way out is to somehow transport the water from the flooded region to the fertile but dry farmlands to the west comprising of Peru's 70% population. The project engineers faced major problems while on a seismically active site with plenty of earthquakes, landslides, and mudslides. Let us see how Peru made it possible.

Keywords : Entrepreneurship, Dam, Flooding, Tunnel

I. INTRODUCTION

A. Requirement of Project

When damage caused by the flooding of Huancabamba river was peaking in the early 1900s, a solution was deeply needed. At the same time on the western region, the duration of drought in a year was rapidly increasing. This drought led to depleting water bodies such as lakes and rivers. 70% of the population in the western region were in desperate need of water and as time passed, its need started to increase.

The region on the east and west were separated by the "Andes mountain" range. These mountain ranges

Fig.1. Areas Affected by Floods and the Destruction Caused [3]

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which are formed by the collision of the Atlantic and Pacific tectonic plates are 7,000 ft high, 5,000 km long and seismically active. These 7,000 ft high mountains prevent clouds coming from the east to travel west. This barrier which prevents clouds from travelling caused clustering of clouds which resulted in very heavy rainfall. The rainfall is so heavy that it flooded the Huancabamba river coming from north and flowing south. The flood in this region destroyed everything in its range. There were reportedly hundreds of people going homeless every year. Many were dead, injured or missing. Every aspect of living creatures was badly hampered. [1]

At the same time, living in the western region became ever challenging. People were alive only with the little underground water that remained. They had to dig wells and used a pulley system to fetch water for anything that required water [3].

Considering all of this and years of suffering, they had to do something about the problem of both regions. A need to somehow transport excess water from the east to a deserted west was deeply felt.

II. TECHNOLOGIES USED

A. Initial Trials and History

In 1924, engineers came up with the idea of building a dam on the flooding Huancabamba river and transporting water through the Andes mountains via a 12 mile long tunnel to transport water to the west. The plan seemed simple but was packed with never before faced challenges. In the first attempt in 1924, engineers tried but did not achieve success. In 1940s – 1950s, they again tried with an add-on feature in the project. They equipped the dam with hydroelectric turbines which would generate electricity as well, but did not get success. Again in the 1960s, they tried with different ways, but this time in collaboration with a Roman company Italconsult but they were not able to complete it.

By the year 1979, Soviet engineers took over and started working on the project. It was estimated to be a 3 year long project, which was to end in 1982. However, due to lack of funding the project had to be stopped in 1980.

B. Making of the Impossible

In 2006, a favourable turn of events led to resumption of the project. Now, the project had $ 600 million funding and fancy equipments such as Tunnel Burrowing Machine (TBM) and self-developed technology such as TSP. Also, this time they reorganised everything and divided the project accordingly. The project was divided into two sub-projects :

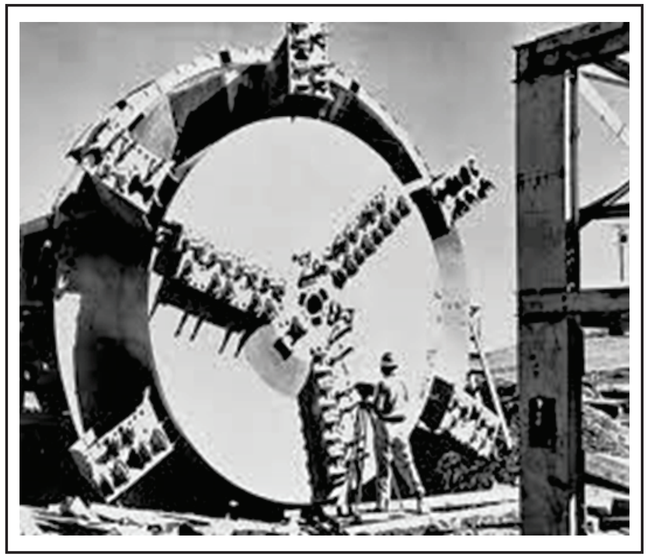

Fig.2. An old TBM [4]

(1) The Limón Dam

(2) The Andean Tunnel

The Limón dam was designed to hold 44 million cubic meters of water brought in by the flooding of Huancabamba River. This dam was chosen to be a concrete faced – rock filled type. There were two main reasons to select this type of dam. One, rocks are cheaper than concrete and second, the dam was to be built on a seismically active region. Upon hitting of seismic waves, the tightly arranged rocks can absorb this seismic energy, whereas, concrete would crack in this case.

The dam has the capacity to hold 44 million cubic meter water at a height of 141ft (43 meter) and is 1,050 ft (320 meter) in length. The face of this dam is inclined at an insane 33 degrees, is 259 ft high and 22 inch thick. This long dam of 1050 ft could not be made in a single go. Thus, it had to be divided into 22 segments which allowed ease of work and also retained quality.

Parallely, the Andean tunnel was in construction. It is a 12 mile long tunnel straight through the Andes mountains. Burrowing a 12 mile long tunnel is a very time consuming task. Thus, this team was divided into

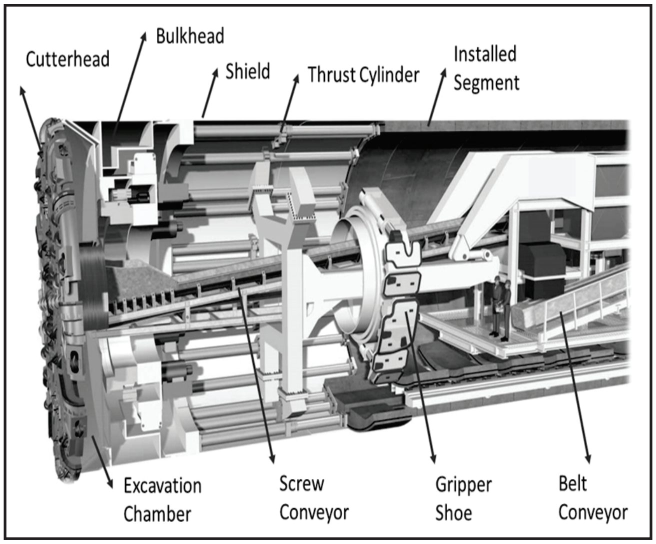

Fig.3. Components of a TBM [5]

two teams for faster success. However, due to a price tag of $ 600 million, they could afford only one TBM.

A tunnel boring machine (TBM) also known as a *mole* is used to excavate tunnels with a circular cross-section through a variety of soil and rock. They can bore through hard rock, sand, and almost anything in between. Tunnel diameters can range from a metre (done with micro-TBMs) to almost 16 metres to date. Tunnel boring machines are used as an alternative to drilling and blasting (D&B) methods in rock and conventional 'hand mining' in soil.

The west team heading towards the mountain got the TBM. It could dig up to 126 ft per day. It is like an earthworm making its way through the soil. While digging, the team across many obstacles. One of them was rock burst.

Rock burst is falling of rocks from above the TBM caused by the immense pressure on TBM applied by the mountains above. This rock burst not only stops TBM from proceeding forward, but also makes workers vulnerable to accidents. The cavity made by the rock burst has to be filled with concrete in order to move the TBM forward. Another challenge to this TBM was the lava rocks it was cutting through. Lava rocks are very hard and eat the TBM head.

On the other hand, the team working on the dam made great progress. They divided the 1,050 ft face of the dam into 22 sections making it about 47 ft at a time to cover. The work was done using a concrete pump to supply concrete at the required height and a roller to make a smooth and flat face. A dam made upon a heavily flooded river needed a smart design, so the engineers installed a secondary gate or the maintenance gate parallel to the main gate. The main gate will be used to relay water when needed. In case of breakdown of main gate, maintenance gates would be closed and water was drawn out for the safety of workers to get there and repair the main gate. By following protocol and with great devotion, within three years the dam was completed. The dam was ready in 2009.

The west and the east teams working on the tunnel faced even more complications as they headed for the heart of the mountain. One of the major problems was the immense humid and hot working site. This construction of Trans Andean tunnel was beneath 1.3 miles of the mountain top. With every 300 ft towards the mountain, one degree Fahrenheit temperature increased. By the time workers reached halfway in, it was 114 degree Fahrenheit making it impossible to work in this environment. To solve this problem, they used a forced air cooling system.

A forced air cooling system is used to drive out the heat from one place and throw it out. In normal systems, cold air is supplied to the desired place and a small empty cross section as a ventilation is somewhere on the other wall for the heat to drive out of the place, which is a sluggish process and is overdamp. However, in a forced air cooling system, cold air is supplied with pressure to the area and a powerful suction pump is installed opposite to it with a calculated air gap in between. This suction pump quickly drives out the air present in the area making more rapid flow of the cold air. This rapid movement of cold air through the area causes quick decline in temperature bringing the temperature down in the tunnel to a manageable working space. This cyclic system is quick and is critically damped [2].

The eastern team used a traditional way of making the tunnel. They used dynamite to make progress. Thus, they were comparatively slow. By the use of heavy drilling machine they drilled holes into the blasting wall. Dynamites were arranged in a logically planned manner, with each blast giving additional 6ft progress. All this was on schedule.

The western team faced increasing rates of rock bursts every day. They planned to find a solution to this costing time and money which they couldn't afford. They thought of predicting the earth which lies ahead. It was possible to drill holes into the wall with the help of probes to detect a further of 100 meters, but was impractical due to the long

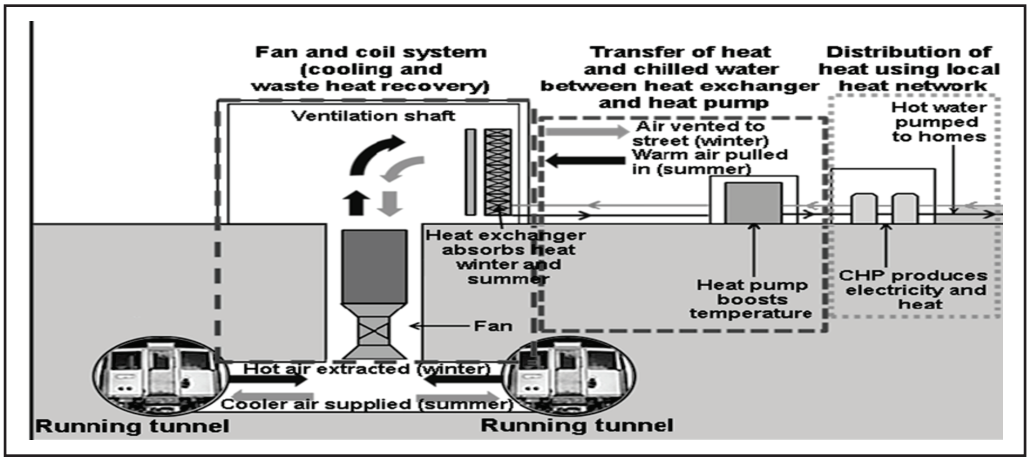

Fig. 4. Concept of Air Cooling System in the Tunnel [6]

hours it consumed. Another method was to drill probes from above the mountain to detect what lies ahead, but was impossible to drill 1.3 miles into the mountain. They came up with something new, and named the Tunnel Seismic Prediction (TSP).

TSP or tunnel seismic prediction is a simple yet useful method. In this method, seismic charges are to be drilled perpendicular to the TBM. Also, sensors are drilled 7 ft long perpendicular to the TBM. Only 2 sensors are used in TSP. Both are placed opposite each other for better results. The charges are blasted at their place, this created seismic waves which vibrate through the tunnel and mountain in a spherical wave form. The seismic waves travel at different speed in different rock types. The waves penetrate through the mountain and upon bouncing back are received by the two high precision sensors. They result in electric values which help the TSP software to predict what lies ahead in geological manner. Thus, by continuous effort, strong devotion, smart engineering, discipline, unique technology this tunnel was delivered in December 2011.

The extension to this project is a hydroelectric power station and a reservoir to hold water. The 2.2 million cubic meter water from the Andean tunnel was let into the Olmos river of the west, which cultivated 14,000 acres of fertile arid soil into healthy farmlands. The remaining water in Olmos river travelled down where the river is split into two parts. Each part is made to pass through a hydroelectric power station which generated massive amount of electricity.

The hydroelectric power stations work on a simple principle. Water at height is made to pass through a passage leading to a turbine. This water with high potential energy falling on the turbine blades changes the

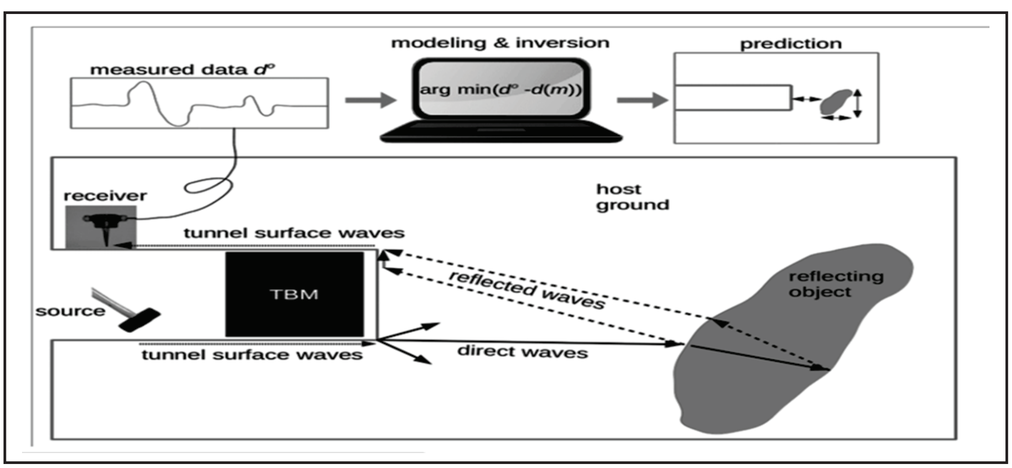

Fig.5. Working Principal of the TSP [7]

Fig. 6. An Almost Ready Tunnel Entrance [8]

kinetic energy of the falling water into mechanical energy as it tends to rotate the blades. The turbine moves the alternator coupled with it and it converts the mechanical energy into electrical energy. This speedy rotation of the turbines generates electricity with a maximum capacity of 600 MW (80,0000 hp). It generates 4,000 GWH annually for the country.

The water from the hydroelectric power station goes back into the Olmos rive. Further, this river travels down and is stopped by the 'Palo Verde' dam. This diversion dam provides water to the remaining 94,000 acres of arid farmlands.

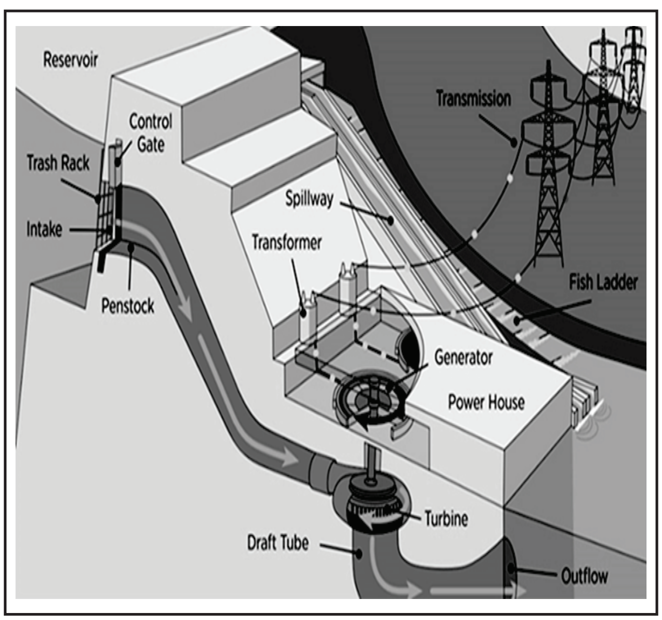

Fig. 7. Structure and Working of a Hydroelectric Power Station [9]

III. ECONOMIC DEVELOPMENT

A. Effects on Local Region

Before this project, people were suffering the extremes of mother nature on the east and west sides of the Andean mountain ranges. More than 70% of the population residing on the western lands were in desperate need of water, whereas the remaining population on the eastern lands were facing frequent floods.

After this project was delivered, people not only got rid of their problems but also gained profit. This profit to the people gave a boost to the country's GDP. Peru soon became an agricultural power house and popular not only in South America, but in the entire world. Due to presence of good quality fertile lands, they grew a wide range of fruits and vegetables in large quantities. These large quantities were more than enough for the country's own needs. They started to export them globally. Due to good quality and cheap prices, they were welcomed world-wide, specially by China. They grow some of the most exotic fruits in the world such as avocados, blueberries, cranberries, citrus fruits, and many more for which the Chinese were willing to pay a premium price. They also cultivated large amounts of sugarcane which led to global investment in sugar refineries on a large scale. It resulted in the country's exponential growth. It soon became the biggest producer of asparagus. This agricultural industry employed no less than 4,000 workers on the farmlands. This project provided 30,000 direct jobs and 100,000 indirect jobs. With such large benefits, people were not only wealthy but happier than ever.

B. Economic Growth

During the last few years, Peru witnessed exponential growth. Despite being a small country, Peru had stable market relations all across the world. With intelligent and good entrepreneurship, they created favourable environment for the country's growth. Between 2002 and 2013, Peru enjoyed an average growth rate of 6.1% annually. From 2014 to 2017, due to global economic crises, the economy fell to 3.0% annually but was still making profit. After 2017, it was back on track. Despite a low current account balance of the country, the country adopted prudent fiscal and monetary policies to address the country's fiscal weakness.

Meanwhile, the country was getting profit from its

Fig. 8. Farmlands Post Olmos Diversion Project - Green and Productive [10]

mining and agricultural projects. This led to increase in exports making favourable conditions for the country. Peru's exports and trading is loved by the Chinese due to their commodities and agricultural goods. Commodities like copper, iron, gold, and other minerals account for around 60% of Peru's total exports. Another 15% – 20% consists of agricultural goods which are exotic, and best in quality at the same time.

China has become the leading market for the above resources since the early 2000s. These relations grew stronger over the years and in 2009, these two countries established a free trade agreement, which allowed 83.5% Peruvian exports to China with zero tariffs. As such, Peru has developed strong independence in exports, specially minerals and agriculture produce due to demand from China and from across the world.

Fig. 9 shows the country's favourable GDP growth over the decade and how the projects and exports have stabilized the country in both revenue and market relations worldwide.

C. Entrepreneurship/Employment

Peru, while developing received around $22.7 billion as loan and FDI from China out of which $22.6 billion was FDI. This shows that Peru did not opt for loans, instead it allowed FDI from China. By the year 2017, there were only 2 loans on Peru which were very less than those on the neighbouring countries. Peru gave control over its mines for the FDI, which not only did well for the country's reputation but also saved its economy. This eliminated chances of Peru becoming bankrupt. It made world-wide trade relations which made it a favourable FDI destination country around the globe, especially among the Chinese. The only two loans on Peru that were

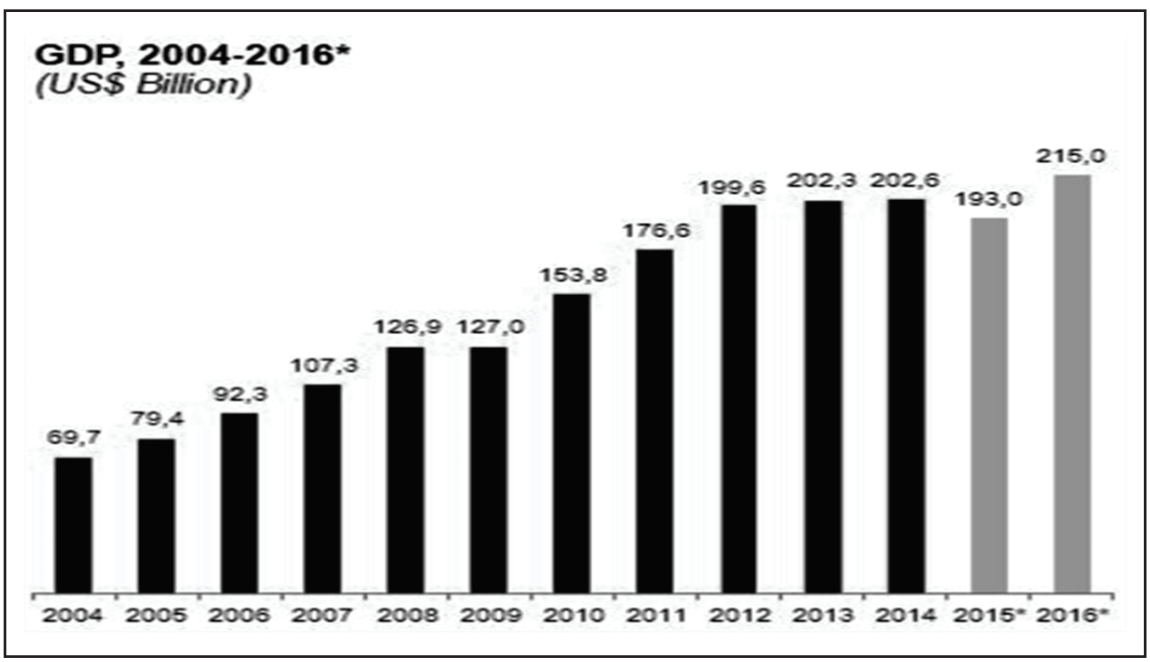

Fig. 9. Peru's GDP Growth Over the Years [11]

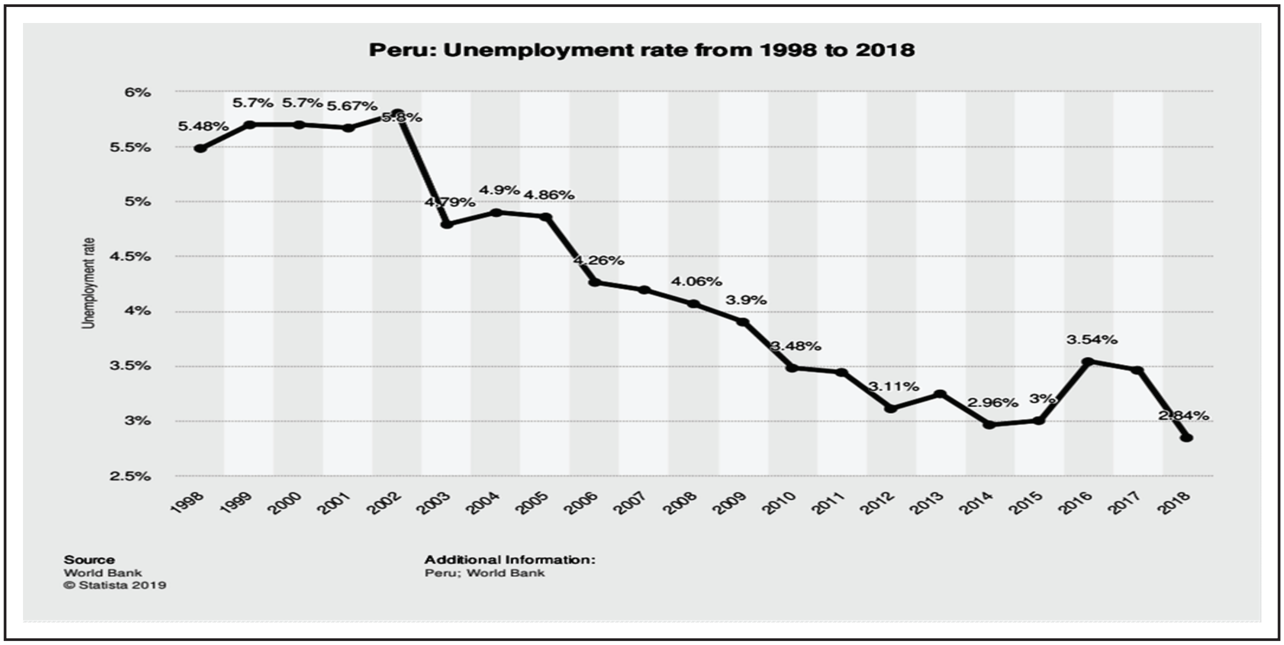

Fig. 10. Peru's Unemployment Rate Over the Years [12]

given by the Chinese Development Bank were to develop the "San Gaban III" hydroelectric power plant which generated enough revenue to pay back the loan on time.

Projects like the Olmos diversion project and mining in the country created more than 1,00,000 direct jobs and over 5,00,000 indirect jobs, and all this without the burden of loan on the country. This creation of employment is the most important thing in the world. Peru's strategic planning slowly brought down unemployment in the country to almost nil. Entrepreneurship in the country created better living standards and conditions for the people. Over the years, people of Peru could afford better food, clothing, medical facility etc., all because the GDP was increasing every year.

Entrepreneurship in the country is so efficient that it almost removed unemployment from the country. Unemployment is the root cause of all evils such as murder, kidnapping, robbery, gang fight etc. Unemployment also leads a country's youth to a destructive path. This destructive path not only ruins them but also the future of the country. The only solution to all this is employment, and the development in Peru produced lot of employment. Eradicating almost all forms of unemployment, Peru is today one of the leading nations in employment rates. Thus, more and better the employment, better is a nation.

IV. CONCLUSION

A country with 80 years of failure in a single project did not give up. They knew that once this project was delivered, it would change the future of their country. With multiple tries, methods, companies and a decade long devotion to their motherland, they finally made it possible. A project which got them rid of extreme of drought and heavy floods. Smart thinking which utilised flood to cultivate arid farmlands and stand against the harsh climatic conditions. With this project delivered, they have all they worked for, such as jobs, food, water, standard homes, education for the young, healthcare and medical facilities and much more. With $ 600 million of investment and years of hard work, this project gives an annual turnover of $156.7 million. With this project, the people of Peru created history on an international level. This project also plays a major role in boosting the GDP. The most important and respected person in this world is the one who gives employment.

V. FUTURE SCOPE

This project is not only possible but desperately needed in many parts of the world where people are suffering from similar situations. In the past few decades, we have seen similar situations in our country where one end is facing trouble with heavy rainfall and another with drought. Countries can build a pipeline parallel to the national highways or major affected areas. This pipeline would help transport water across parts of the country and people will be able to handle similar problems. Talking on a bigger scale, we have witnessed such events across Central and southern Asia. The Olmos diversion project was appreciated worldwide despite all odds it faced. With better resources, technology and investment, the youth of the world today can surely make marvels like this. Everything can be made possible if a nation collectively wishes to do so.

REFERENCES

[1] Limón Dam (n.d.). [Online]. Available: https://en.wikipedia.org/wiki/Lim%C3%B3n_Dam

[2] Extreme engineering deepest tunnel megastructures documentary. [Online]. Available: https://www.youtube.com/watch?v=YotAQrcwSyA

[3] A. Taylor, "Peru suffers worst flooding in decades," The Atlantic, 2017. [Online]. Available: https://www.theatlantic.com/photo/2017/03/peru-suffers-worst-flooding-in-decades/520146/

[4] "Hard – rock tunnel boring machines," *Tunnel Bus. Mag.*, 2014. [Online]. Available: https://tunnelingonline.com/hard-rock-tunnel-boring-machines/

[5] Tunnel Boring Mach., railsystem.net. [Online]. Available: http://www.railsystem.net/tunnel-boring-machine-tbm/

[6] G.F. Davies, G. G. Maidment, W. Dennis, & A. Ajiliye, "Cooling and recovery of heat from underground railway tunnels for district heating," CIBSE ASHRAE Tech. Symp., Loughborough, UK, 5-6 April, 2017. [Online]. Available: https://openresearch.lsbu.ac.uk/download/4daee26bd1d0a541e36b6d0bb1709c5e68854fad396492ca0cd56cd459ebc6c7/701695/Cooling%20and%20recovery%20of%20heat%20from%20underground%20railway%20tunnels.pdf

[7] L. T. Nguyen and T. Nestorovic, "Reconstructing disturbance zones ahead of the tunnel face by elastic waveform inversion supported by a parametric level-set representation," *Soil Dynamics and Earthquake Eng.*, vol. 155, pp. 606-621. Doi: 10.1016/j.soildyn.2018.09.025

[8] Chiciayo, "Olmos project to strengthen Peru-Ecuador integration," *Andina*, 2012. [Online]. Available: https://andina.pe/ingles/noticia-olmos-project-to-strengthen-peruecuador-integration-402120.aspx

[9] A. Singh, "Principles of renewable energy telecgies – biomass and hydropower," 2018. [Online].Available: https://iopscience.iop.org/book/978-1-6817-4901-3/chapter/bk978-1-6817-4901-3ch2

[10] Farmlands post Olmos diversion project. Green and Productive. [Online]. Available: https://www.pinterest.com / pin/410812797242868859/

[11] P. Wiggins, "Why invest in Peru? Macroeconomic Soundness," *ProInversion*. [Online]. Available: https://slideplayer.com/slide/10784817/

[12] Statisa, "Peru: Unemployment rate from 1999 to 2019," [Online]. Available: https://www.statista.com/statistics/459341/unemployment-rate-in-peru/

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