OPTIMIZATION OF THE DESIGN OF IRRIGATION AND DRAINAGE NETWORKS USING VALUE ENGINEERING – CASE STUDY ; JOFEIR IRRIGATION AND DRAINAGE NETWORK, SOUTH WEST OF IRAN

OPTIMISATION DE LA CONCEPTION DU RESEAU D'IRRIGATION ET DE DRAINAGE UTILISANT LE GENIE DE VALEUR – ETUDE DE CAS : RESEAU D'IRRIGATION ET DE DRAINAGE JOFEIR , SUD-OUEST DE L'IRAN

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ABSTRACT

According to united nation Food and Agriculture Organization estimates, the extent of irrigated lands in developing countries between the years of 1999 and 2030 should increase by 20% or 40 million hectares to enable them coping up with their ever increasing population (FAO 2002). One of the effective methods of ensuring the success of such irrigation and drainage projects is value engineering. Review of the reasons of success or failure of numerous irrigation and drainage projects has shown that using the experiences of the on-going projects can play a significant role in optimizing and improving the irrigation and drainage systems. The structure of group work in the value engineering method makes it possible to consider the operation phase experiences of one project to be implemented during the design stage of another project.

Jofair irrigation and drainage project, part of Karun River's basin, with a gross area of 40,000 hectares is located in Khuzestan plain, south west of Iran. Because of delays between the design and construction stages, also due to change of the department

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responsble for the project from agriculture ministry to water and power ministry, it was decided to carry out value engineering studies for this project through preliminary study, data Analysis, function analysis, determining the areas for improvement, gathering ideas and opinions, for optimizing the design.

As the result of this value engineering studies nine changes in this project were suggested which result in reduction in costs and investment. They are: using hydro flumes instead of grade four canals, using a low pressure irrigation system, reflection on the transfer canal design taking note of earth quality, use of a land leveling in some sections of lands, reflection on determining the capacity of canals, reducing the depths of the drainage and the distance between the drains, change of material and diameter of collectors, using decentralized pump stations for disposal of waste waters.

Keywords: *value engineering, Hydro flume, low pressure pipelines, drainage depth, collector, drain water, system layout, flexibility coefficients*

RESUME

Selon les estimations de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), la superficie des terres irriguées dans les pays en développement entre les années 1999 et 2030 devrait augmenter de 20% soit 40 millions d'hectares pour leur permettre de faire face à la croissance démographique (FAO 2002). L'une des méthodes efficaces pour assurer le succès des projets d'irrigation et de drainage est de génie de valeur. L'examen des raisons de succès ou d'échec de nombreux projets d'irrigation et de drainage a montré que l'utilisation des expériences acquises des projets en cours peut jouer un rôle important dans l'optimisation et l'amélioration du système d'irrigation et de drainage. La structure de travail en groupe dans la méthode du génie de valeur permet à utiliser les expériences de la phase d'exploitation d'un projet lors de la phase de conception d'un autre projet.

Le projet d'irrigation et de drainage de Jofeir fait partie du bassin fluvial de Karoun, avec une superficie brute de 40 000 hectares de terre est situé dans la plaine de Khuzestan au sud-ouest de l'Iran. En raison des retards entre les phases de conception et de construction ainsi qu'en raison du changement de département chargé du projet - du ministère de l'agriculture au ministère d'eau et d'énergie - il a été décidé de réaliser les études sur le génie de valeur pour ce projet par l'étude préliminaire, l'analyse des données, l'analyse de la fonction pour déterminer les domaines d'amélioration, la collecte des idées et des opinions et optimiser la conception.

En raison de l'étude du génie de valeur, neuf changements ont été proposés dans ce projet pour la réduction de coût et d'investissement. Ce sont : utilisation des canaux hydrauliques au lieu des canaux de niveau quatre, utilisation d'un système d'irrigation à basse pression, réflexion sur la conception du canal de transfert en tenant compte de la qualité de terre, utilisation d'un nivellement des terres dans certaines sections de terres, réflexion sur la détermination de la capacité des canaux, réduction de la profondeur du drainage et de l'écartement des drains, changement de matériau et de diamètre des collecteurs, utilisation des stations de pompage décentralisée pour l'évacuation des eaux usées.

Mots clés: *Génie de valeur, canal hydraulique, tuyaux à basse pression, profondeur de drainage, collecteur, eau de drain, plan du système, coefficients de flexibilité.*

1. INTRODUCTION

The upward trend in investment in national projects and the resources limitation have resulted in paying particular attention to optimization of resources as an essential process in projects management. A reflection on the success and failure of numerous projects brings this clear and important conclusion that paying attention to the various stages of design plays significant role in the success of the projects at minimum possible cost and maximum possible quality. Sufficient deliberation in design stages of the project and making use of experienced and innovative designers and consultents, not only reduces the cost and improves the quality, but also makes it possible to achieve the goals of the project according to the needs and requirements of all beneficiaries. One of the effective and practical approaches in projects studies is through value engineering. Value engineering is one of the methods with a systematic application of sound scientific principles and relying on innovation and team work. For the present study, value engineering was applied to the “Jofair Irrigation and Drainage Network” (IDN) Project, which was planned in 1998 but the construction got delayed due to various reasons.

2. THE JOFAIR IDN PROJECT

Eesargaran cooperative irrigation and drainage network project (Jofair) is an irrigable part of Karun river, with a gross area of 40,000 hectares, situated 25 km south west of Ahvaz town in the east of Karun River. The rate of allotted water rights to the project has been determined at 40 cm and the design of this IDN project is based on these figures. The cost of this project has been estimated at 350 billion tomans[5].

For the purpose of taking water and supply of energy for the transfer of the water needed by these lands from the river a pump station will be used. This water will be transferred to the beginning of land through a canal, which is located at fill section, and then it will be pumped from there to the project lands by a second pump station. Due to the very low angle of slope of the lands in this area all the irrigation canals of the network have been designed at fill section. These canals comprise a series of main canal, 5 series of preliminary canals and 32 series of secondary canals. The main network of Jofair drainage comprises of a series of main canal, one of preliminary drains and 12 series of secondary drains with a total length of 230 km. The waste water of the preliminary drains is discharged into the main drains of the project and then it is transferred to the outside of the bounds of the network by the pump station of the main drainage. This station is situated at the very far end of south west of the project lands near the border guard sation of Koushk.

5 1 Iran toman = 10 Iran rials. 1 US dollar = 10,000 Iran rials.

3. VALUE ENGINEERING OF THE PROJECT, THE PRINCIPLE AND THE OUTCOMES

The value engineering workshop of Jofair IDN project was held with the participation of value engineering team members comprising the project's employer, the designer consultant, the contractor, the value engineering consultant, the water users, the university lecturers, free-lance experts and financial experts. This work shop studied the feasibility of optimizing and reducing the costs of this project in irrigation and drainage network layout, the principles of design of irrigation system and also the underground drainage system. This article will review the outcomes of application of value engineering method in the principles of design of surface irrigation networks of Jofair IDN.

According to the value engineering system, the effective and key factors in the success of the project from the team member's point of view should first be identified and defined. These criteria will be the evidence in valuing and grading the ideas in the process of optimizing in value engineering. The standards emphasized by the value engineering team members in Jofair IDN are as out lined in the following list:

1. Protection of the environment
2. Ease of operation
3. Ease of construction
4. Reduce the investment costs
5. Possibility of producing the materials or supply them locally
6. Access to construction technology
7. The possibility of construction and operation of the project in different phases.
8. Reduce the operation costs.

3.1 Using hydro flumes instead of head ditch canals:

The descriptions of preliminary design: In the preliminary design a series of head ditch canals are used on the upstream of each farm (in an approximate area of 10 ha) for irrigating each border strips.

The description of suggested design: A series of flexible pipes equipped with gates will be used in place of the unlined canals. It seems that it takes only a third of the time to do the suggested design in comparison to the preliminary design taking into consideration the fact that the hydroflumes are already built. To executer this project, around 600 km of foundation installations exists and the production technology of this product in available in the local sugar industry's subsidiary companies. Hence, there does not seem to be any problems in supply of the needed product for this project. Considering the 3 years useful life of hydroflumes, in comparison with 3 times construction and demolition cost of head ditches in that period, there is no difference in the investment costs with the original design.

Advantages and quality outcomes:

1. Improvement in water distribution efficiency.

2. Elimination of head ditches costs at the end of each cultivation cycle.
3. Ease of operation
4. Speed of implementation of operations
5. Elimination of application of syphon.
6. An average useful life of 3 years
7. Better control and regulation over distribution of water in the farms
8. Reduction in the wasted area of the farms
9. Reduction in labour costs.

The disadvantages and the risks of construction:

1. The blockage problems caused by low quality water
2. The problem of breakage by animals or inappropriate operation
3. The increase in the needed head in the canal and consequently the extra earth work needed be cause of this excessive height, in the grade three canals.

3.2 Using a low pressure irrigation system

Description of preliminary design: For irrigation of the agricultural regions (in about 120 ha) the trapezium concrete canals of grade three are used in the preliminary design over a length of 1000 m for each area.

Description of suggested design: PE or GRP pipes measuring 60 cm in diameters can be used instead of tertiary canals, because for the first 70% of secondary canals, there is sufficient head for the low pressure irrigation system to be used. The speed of water in such pipes is about 0.8 m/s and the speed of the module in use is 2 l/s. The technology of manufacturing these pipes already exists in Khuzestan province and the country. A bout 300km of tertiary canals have been forecast for the whole project. Taking into consideration that low pressure irrigation system can be used in 70% of these canals (210 km) and the duration of 4 years construction period, about 53 km of pipes in needed in a year. According to the estimations carried out, the cost of implementing this method in comparison to the preliminary design, there will be a 14% reduction in cost and 60% reduction in the time taken for construction of secondary irrigation network in the method using this technique.

The advantages and quality out comes:

1. Improvement in the transfer efficiency due to reduction in subsidence.
2. Reduction in wasted agricultural lands
3. Ease of protection of pipes against the natural elements
4. Ease and speed of implementation.
5. Elimination of grade three canal's excavation operations and reduce the need for material loan resources.

The disadvantages and the risks of construction:

1. The need for excessive head at the beginning of the canal.
2. The need for a pressure regulating structure at the junction of grade 3 & 4 canals.
3. Taking into consideration that agriculture with the above forecast module of (2 l/s) may not materialize in a 100 ha farm, thus the speed is reduced and sedimentation may occur.

3.3 Reflection on the conveyance canal design taking note of earth quality:

Description of preliminary design: The conveyance canal will be constructed at a depth of 4 meters and the produced earth from the excavation will be used as a source of loan material. These materials are used for canals in fill sections.

Description of suggested design: Taking into consideration the existence quick sand layers in depths of between 2.5 and 4 m in the canal route, some solution for stability of the canal side slope must be reached. In order to obviate this problem it has been suggested to keep the depth of the conveyance canal to only 2.5 m at most and to make up for the lost depth, widen the canal. As a result of implementation of this solution, not only the problem of facing the layer of sandy soil will be avoided but also there would not any stability problems in the conveyance canal. Besides, due to canal widening a higher volume of earth suitable in other parts for the project will be obtained. These changes will result in a nearly 40% reduction in the duration of transfer canal operation execution and almost 15% savings in costs.

Advantages and the quality outcomes:

1. Ease of construction
2. No need to carry away the unsuitable extra sand
3. Improvement in the quality of extracted earth as loan material resource.
4. Reduction in unnecessary costs incurred by longer periods of construction
5. Reduction in maintenance costs during operation.
6. Elimination of sandy bed stabilization costs.
7. Reduction in water leakage into the canal construction area during the operations and reduce the problems and costs associated with pumping out the extra water.
8. Reduce the costs of operations execution at under ground sub water levels.
9. Sustainability and stability of structures during operation period due to reduction in uplifting pressure caused by underground water levels.

The disadvantages and risks of construction:

1. Reduction in efficiency of water transfer of water caused by larger wetted area.
2. Increase in problems associated with dredging and operation
3. Increase in owner ship of lands.

3.4 Use of a relative leveling in some sections of lands:

Description of preliminary design: Basic leveling operations project in the whole land in order to create a suitable slope for irrigation operations.

Description of suggested design: The leveling operations will be eliminated. In order to be absolutely certain of this decision, it is necessary to implement this method in a few pilot farms and by taking notice of the collection of factors affecting the application of irrigation operations, the quantitative value of the elimination of leveling operations are to be studied and then the decision in regard to necessity or redundancy of leveling operation will be taken accordingly.

Advantages and the quality out comes: The soil of the farms will remain untouched and would not be subjected to changes in its shape after the very first irrigation operations

The disadvantages and the risks of construction: Irrigation efficiency will be reduced where proper irrigation is not possible due to the unsuitable topography of the land.

3.5 Reflection on determining the capacity of canals:

Description of preliminary design: As rice is a popular product for consumption by the people, the canal capacity has been determined based on this fact of highly needed product and this basically 2.73 l/s in each hectare of cultivation land. In addition to that the flexibility coefficient, relative to the land covered by the canal has been considered in designing the canals which is between 1 and 2.33.

Description of suggested design: it is suggested that the calculation of hydromodule irrigation is be used in multi cultivation farms and reduce the flexibility coefficient to its minimum. It seems that reduction of about 20% in hydromodule of the farm can produce saving of about 15% in the whole operational costs of secondary canal in the form of unlined canals in fill section. This would materialize when the construction of secondary network in the shape of low pressure pipes occurs and reduction of this rate of discharge would necessitate the use of pipes with lower diameter and would resulin more substantial savings in the costs. Application of hydromudule and new coefficients in the main canal will create reductions of about 15% in the dimensions of canals and savings of about 10% in the main network, while this would reduce the rate of taking of water, this would also result in costs of operation of the network

Advantages and the quality out comes:

1. Increase in irrigation efficiency because of inaccessibility of extra water.
2. Reduction in seepage and prevent lands to be water logged.

3.6 Reducing the depths of the drainage and the distance between the drains

The preliminary design: the depth of the lateral drains in the preliminary design was 1.9 to 2.1 m and the distance between the drains was around 55m.

The proposed design: Similar experiences in other projects have shown that the underground water is also discharged when the drains are in excessive depths. Discharge of the saline underground water in addition to undesired adverse environmental effects on the waste water recipient point, it also involves heavy costs in pump energy consumptions and wear and tear and maintenance, even in non harvesting periods of the year.

Reducing the depth of the drains will ease in construction and will speed up the adjustment of the salinity in the lands and the salinity degree of the waste waters in the lands will reach a balanced level in a shorter time. In addition in case of excessive depth of the drains, due to higher hydraulic gradient, the discharge is faster, as a result of which the water needed by the plants becomes unavailable and consequently the next irrigation must be done sooner. Therefore reduction in drainage depth has a significant role in increasing the water application efficiency and in preventing excessive drainage. In addition, due to higher position of laterals the underground saline water has less chance of entering the lateral pipes and the salinity of waste water will be reduced, which will be environment-friendly. Therefore it is suggested that the lateral drains depths are limited to 1.5 m and the distances between them is also reduced accordingly.

3.7 Change of material and diameter of collectors

The preliminary design: The concrete collectors have a diameter between 20 to 25 cm.

The proposed design: The calculation of the collector diameter has been done based on the drainage coefficient in the life of operation, but experience has shown that the discharge of collectors during the preliminary waste water operations is much more and the calculated diameters based on the drainage coefficient of cultivation season is not sufficient for the leaching periods. Therefore the diameter of the pipes should be calculated based on the discharge during the preliminary leaching periods for it to be sufficient.

The second point to remember is that in a vast area of the project lands, There are layers of sand with very low adhesion and taking into consideration that the operation level of collectors is below the ground water levels, gradually over a period of time these particles, with the flow of ground water will enter the collectors via the spaces between the lengths of concrete pipes and would form sand cones and cause the pipes to subside.

In order to circumvent this problem PE pipes can be used. These pipes are joined together by welding and it would solve the problem of sand entering the pipes. In addition as the lengths of PE pipes are longer than concrete pipes, their installation would be faster.

Advantages and quality out comes:

- Ease of leaching operations
- Sedimentation problems and the problems during operation period will be reduced
- Change of material of pipes used will speed up the operational activities problem of the particles entering through the cracks at the joints will be reduced considerably and would eradicate the possibility of sand cones forming inside the pipe and their subsidence

3.8 Using uncentralized pump stations for disposal of waste waters

The preliminary design: In the preliminary design a centralized drainage pump station was to be used for all the land.

The proposed desigin: Taking into consideration the vast area of the project (40,000 ha) the construction of this project needs a long time to complete and it is recommended to divide the project in phases so that its construction and operation could be done phase-wise. While the original centralized drainage pump station would have had to be installed a lot deeper, which would have involved not only much harder operational works but it would have also made the user incur higher pump energy costs. While in phase-wise work, constructing decentralized pump station makes it possible to reduce the height of pump station, which would result in considerable reduction it energy costs.

Advantages and quality outcomes:

- It makes it possible to do the project in different phases.
- The exploitation duties can be transferred to private sector or cooperatives.
- The height of the pump station is reduced.
- The quality of waste water would be improved

REFERENCES

Dez ab Cons. Eng. The report on development of Jofair's irrigation and drainage network project, 1998

Mr. Mir Mohammad Sadeghi, Sayed Ali Reza Safdel, Ali Safaee and Shaheen The value engineering society's book, Farat publication, 2009.

Sazab Pardazan Cons. Eng, the value engineering report of Jofair irrigation and drainage network project, 1998

Zarghami, Mehdi, using value engineering in deriving the evaluation criteria for development projects in water sections. The second value engineering conference, 2005.