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EARLY INVOLVEMENT OF FACILITIES MANAGEMENT TOWARDS EFFICIENT UTILIZATION

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Abstract: Investors are keen on ensuring long-term investments by avoiding deterioration of valuable assets. Accordingly, Facilities Management (FM) has been a crucial management approach. Involving FM earlier in the engineering and construction phases of the desalination plants would lead to significant savings and optimized reliability. In light of the future global water crisis, desalination plants are considered a major capital investment for Real Estate mega projects nowadays. The purpose of this paper is showing the importance of this practice through actual case studies of two Sea Water Reverse Osmosis (SWRO) desalination plants. Both SWRO desalination plants have same to similar parameters. A failure trend analysis was conducted to reflect the production reliability of both cases, taking into consideration the timing of FM involvement. Afterward, a cross-comparison was carried out between the data sets of the two case studies to render tangible results of 27% improvement in reliability when FM is involved early. The results signify the better utilization of the asset when FM is involved in an early stage in the project. The early involvement of FM team achieves better utilization of the desalination plant, ensuring an added value to the investment, as well as the overall assets useful lifetime and efficiency.

Keywords: Facilities Management, Project lifecycle, Desalination plants, Failure analysis, Reliability, FM early involvement.

1. INTRODUCTION

Due to the lack of awareness with the term of Facilities Management (FM) in Egypt, the FM team isn't always involved from the early stages of the project, engineering, and construction. But, the FM team is introduced in the handing over and commissioning stage. As the engineering-construct cycle proceeds, changes become costlier and less effective (Roper and Payant. 2014). However having early involvement of FM controls both quality and cost. Stakeholders are beginning to acknowledge the importance and vitality of involving FM as early as the project lifecycle starts.

Water is a major input for economic development. The importance of water increases as the demand for water surges, which leads to forecast a global water crisis. Water resources management in Egypt has witnessed rather top-notch technologies introduced to the business to cover water demands. This is due to the rare rainfalls and the governmentally enforced quota for withdrawal from the River Nile, which was not changed since 1959 (El Bedawy, 2014). So, the rise of the need for desalination plants and Sea Water Reverse Osmosis (SWRO) plants is implied. SWRO uses surface intakes from seawater or wells as its source of water. Then, filtration is applied to it in the pre-treatment process, which is after the treated water is pumped at high pressure against membrane elements. The membrane elements separate salts, minerals, and impurities from source water and produce drinkable water using the reverse osmosis phenomena. Figure 1 presents a schematic diagram for the process flow diagram of a typical SWRO (Voutchkov, 2013).

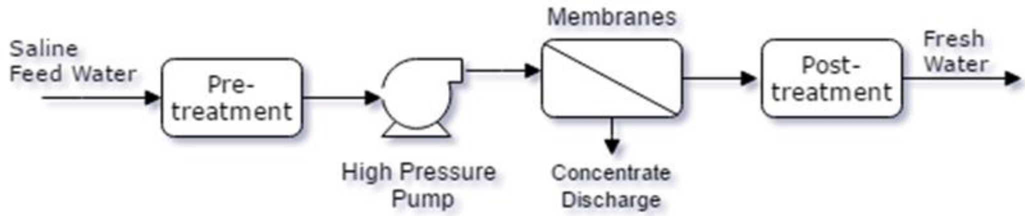

Figure 1: Process flow diagram of a typical SWRO

2. LITERATURE REVIEW

A Desalination plant is an asset investment with high initial capital costs of an average 1,065 $/m3 of water produced that represents the combined direct and indirect capital costs. This capital cost characterizes the largest portion of the project lifecycle costs, which is about 45% of the lifecycle costs, as illustrated in Figure 2 (Voutchkov, 2013). This leads Real Estate investors to think of the construction phase as the most crucial, as it’s always governed by time constraints over a considerable amount of money invested in short periods of time. This signifies the importance of implementing cost control methods. The engineering and construction phases of the project comprise only 15% of the project lifecycle, while the remaining 85% being assigned to the operation and maintenance (Devetakovic and Radojevic. 2007).

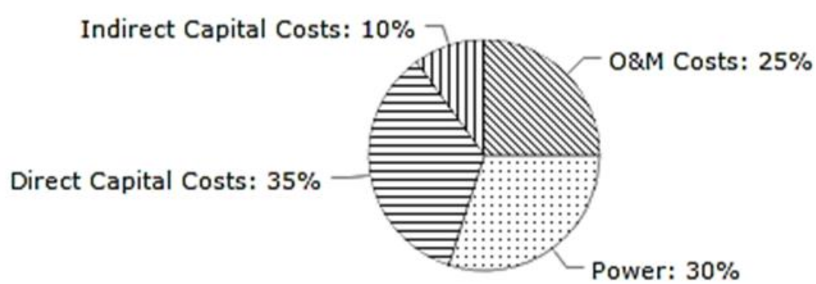

Figure 2: Cost of water breakdown for SWRO plant over its useful life

Desalination plants are considered interconnected processes that together form the function of producing drinkable water out from source water (Sea or brackish). So, many small parameters can drastically affect the overall performance of the desalination process (Voutchkov. 2013). The FM with its broader management techniques, information and operation history data offers a deeper understanding of some of the areas. It may not be as apparent to the engineering or construction parties, hence, achieving a far efficient and more beneficial cost saving both at early stages and at the operation stage (Enoma, 2005). The rather critical aspects that should be kept in check are listed below:

2.1. Legislative requirements

Making sure that all legislation papers are properly issued and that the plant follows all legislative requirements. It is a bid task and it adds a weighted cost according to the project’s complexity (Voutchkov. 2014). The FM team by the nature of its work stands always a step ahead in matters of legislations and incorporating. The FM as early could lower the initial cost and avoid unforeseen contingency costs at the operation phase (Enoma, 2005).

2.2. Operation Requirements

The FM is the party concerned with the operation and could enhance reviewing the engineering documents to make sure that no changes or upgrades will be required during operation. This could reduce significantly the adjusted variation orders over the contract issued. Furthermore, managers not in facilities department do not realize the cost of late operational decisions that affect engineering or construction. As the decisions made in the conceptual and schematic phases have the greatest impact and the least cost commitment (Roper and Payant. 2014).

2.3. Material Selection

Quality materials ensure that a long-term capital investment and maintain a useful life that is adequate to an investment as desalination plants. Experienced FM senior personnel could identify at once the point of weaknesses in the selected materials from previous historical trends and information models that later shape into a solid guideline for decision taking (Atkin and Brooks, 2009).

The concept of involving the FM early in projects is new. However, the need for applying it is becoming crucial to allow for greater awareness of the cost over the whole life of the facility and to reach an optimum use of the whole lifecycle cost (Enoma. 2005). FM also offers a weighted tool in the hands of stakeholders to utilize in the early project lifecycle. Having the capital cost so visible that there is always a greater pressure to minimize initial cost and bring the project in at the earliest possible dates. Often this ensures sub-optimizing the life-cycle costs, which typically are three times the capital costs (Roper and Payant. 2014).

The objective of this paper is to study the impact of involving Facilities Management early in the project lifecycle, this objective was be achieved through the following:

1. Literature review to stand on the importance of FM early involvement
2. Establishing a case study to identify FM early involvement importance
3. Case study data collecting and refining
4. Failure analysis through a reliability-oriented maintenance model
5. Compare failure analysis data for each case then commenting on findings

Rather than the more conventional Key Performance Indicators (KPIs), a particular performance analysis procedure was considered in approaching the paper objective to properly measure the equipment, process and cost effectively. Reliability modeling was chosen because management can achieve the lowest total costs possible if reliability is maintained at a high level (Hajeeh et al., 2007).

Most facility managers tend to think about efficiency ignoring the sound effect of reliability and RO plants must be reliable for a continuous supply of water. The term “reliability” in engineering refers to the probability that a product, or system, will perform its designed functions under a given set of operating conditions for a specific period of time. It is also known as the “probability of survival” (Raju. 2011). Reliability management of a system is a systematic approach to identifying and assessing the causes and frequencies of its failures, and reducing and/or controlling the effects of failures to provide the satisfactory performance of the system to the society (Bazovsky, 1961). Since continuously-operated systems can tolerate failures, the systems can be restored to an operational level by carrying out the required repairs and maintenance. For such continuous systems, a more appropriate performance measure is availability, which is defined as the probability that a system or component is performing its required function at a given point in time or over stated period of time when operated and maintained in a prescribed manner (Eblening, 1997). These maintenance intervals could charge extra cost in order to restore the reliability of the system unless higher reliability could be achieved during the engineering stage. The frequencies of such events are assessed during the design stage of the system. In order to derive the maximum benefit, reliability analysis of such a system has to be made at the design stage and it should be carried on until the system is finally replaced (Hajeeh, Faramarzi and El-Essa. 2007).

3. RESEARCH METHODOLOGY

The main objective of this paper is to emphasize the importance and effect of FM early involvement. It was done through solid quantifiable data and comparing two separate data sets from two cases, which had FM involved at different timing each. This objective was achieved through failure analysis and trending efficiency of both cases, which reflects how much reliable is the maintenance and the plant itself. The data showed different trends for maintenance reliability while applying the same maintenance methods for both cases highlighting the issues at the engineering and construction phases. The data collected are field-acquired, which is the most efficient data for the representation of the system reliability and maintainability characteristics (Raju. 2011). The data went through a refining and inconsistencies removal process as follows:

1. Failures independent from the Reverse Osmosis (RO) technology were removed such as failures from power supply and human error to model the reliability of the RO process alone and its embedded defects (Hajeeh, Faramarzi and El-Essa. 2007)
2. The system of RO process was taken as a whole to be single system, as the failure in an equipment means the discontinuity of service in real estate's capital investments (Hajeeh, Faramarzi and El-Essa. 2007)

Each data set is descriptive of one system, which is taken to be the whole plant in each case respectively. The data of concern are the Time-Between-Failure (TBF) which are collected for the plants. Time-Between-Failure (TBF) is the time registered between two consecutive failures for a system, while Mean-Time-Between-Failure (MTBF) is the average time between system failures of the entire sample population. MTBF is used when the system is repairable and it reflects the reliability of the plant (Raju. 2011).

Reliability modeling is adopted after refining the data from errors and inconsistencies and was fit into an exponential distribution as illustrated in Figure 3. The field data were analyzed using both analytical and graphical models to test for the presence of trend as follows:

1. Eyeball analysis: A simple analysis tool for testing the presence of a trend in which one passes his eye through chronological TBFs and search for increase of decrease of the failure rate. The magnitude of TBFs could be decreasing towards the end indicating an increasing failure rate, or it could be increasing towards the end indicating a decreasing in failure rate, or if the magnitude is constant throughout the period, then it shows constant rate of failure (Raju. 2011)
2. Cumulative Plot Test: The robust graphical tool to verify the test for trends. TBFs are used in chronological order, then the cumulative time between failures (CTBF) is then calculated and plotted against the cumulative number of failure (Raju. 2011)
3. Scatter Diagram: applied on cases which have fewer failures samples, and to test for correlation and determine the best fit trend, a scatter diagram is used, the coefficient of correlation *r* was found out to be 0.84 with a strong positive correlation, R^2 is a special case of the coefficient of determination here which estimates the fraction of the variance in i^{th} TBFs which is explained by $(i – 1)^{th}$ TBFs in simple linear regression (Raju. 2011)

The process of the desalination plant is a reliable process and thus it's fit for the suggested algorithm illustrated in Figure 3 and stated in the stages below:

1. Trend Analysis*:* Trend analysis is directed to showing the condition of the process or system and whether the equipment is deteriorating or improving (Raju. 2011). It was carried with the graphical tools stated above in both cases
2. Karl-Pearson Coefficient of Correlation*:* Is a measure of linear dependence in serial failure data. To test the data for serial correlation, $(i – 1)^{th}$ TBFs are to be plotted against i^{th} TBFs of the failure data. The coefficient of correlation (r) can be calculated using Eq. 1 (Raju, 2001) as follows:

[1] $$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Having r as the coefficient of correlation
$\bar{x}$ is the sample mean, and analogously for $\bar{y}$
X is the sample data set of TBFs as $\{x_1,\ldots,x_n\}$
Y is the sample data set having $Y_i = X_{i-1}$, and values of *r* near 1 and -1 indicates linearity and serial correlation, while a value of zero implies that there is no serial correlation between the variables (Raju, 2001)

3. Reliability curve is then plotted against time using Eq. 2.

[2] $R = e^{-\lambda t}$

Where R is the reliability in time = t (Hajeeh, Faramarzi and El-Essa. 2007), and $\lambda = 1/_{MTBF}$

The Mean-Time-Between-Failure (MTBF) is the average value of TBF for each case respectively. However to properly cross-compare the reliability of two systems, reliability was calculated at the average MTBF of both systems, so that difference in reliability is calculated after a fixed time interval in both systems.

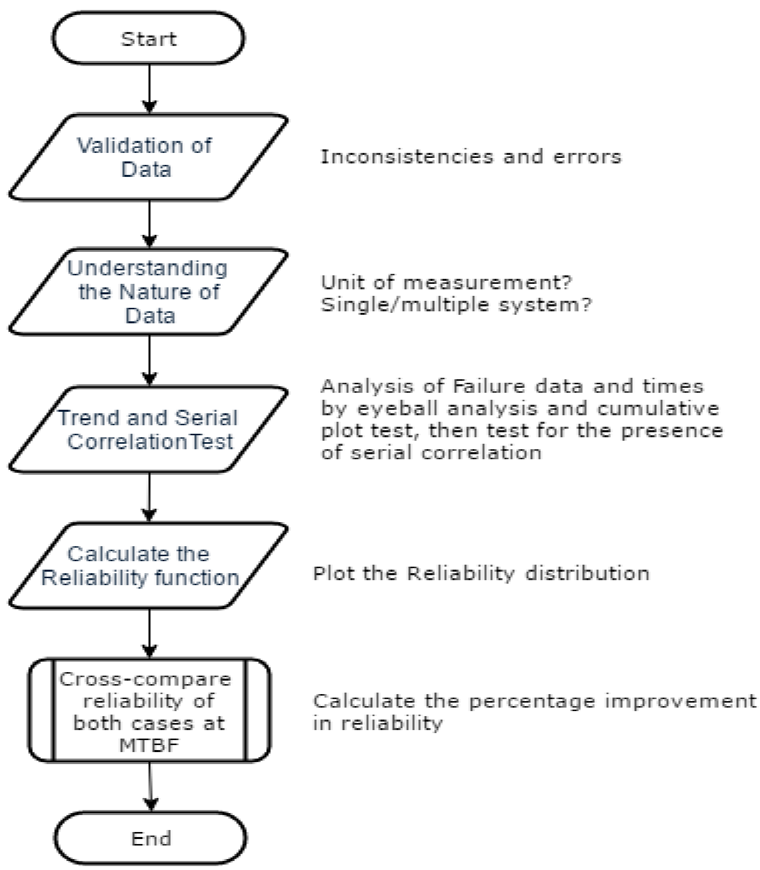

Figure 3: Analysis methodology

4. CASE STUDY

FM was introduced at different points in time to two desalination plants in Egypt with capacities of 5,000 m3/day (A) and 7,500 m3/day (B) respectively. Both desalination plants were compared to their performance via a failure rate trend. The early involvement of FM affects the performance, utilization, and Operation and Maintenance (O&M) expenditures during the useful life. The two cases had common features shared between the two cases to normalize the variance in data, the features were:

1. Management team was the same in both cases
2. The operator is the same in both cases as well, which significantly lowers the inconsistencies in collected data

Table 1. Represents the main points of comparison between both cases noting that in Case (A) the FM wasn't introduced early at the project lifecycle while in Case (B) the FM was involved in the engineering and construction phases just giving advice, sharing operation data to better suggest and develop better processes, advise the selection of better materials, etc…

Table 1: Comparison between the two desalination plants.

Parameters	Case (A)	Case (B)
Project Delivery Type	Design - Build	Design - Build
Plant capacity	5,000 m^3/day	7,400 m^3/day
Actual production	2,500 m^3/day	5,000 m^3/day
Electricity cost (LE/m^3)	7.35	4.56
Utilization*	34%	45%
Contract sum	13,000,000 EGP	20,000,000 EGP
Approved VOs**	1	2
VOs sum***	1,500,000 EGP	8,600,000 EGP
Useful life	20	20
FM involvement phase	Handing over	Engineering & construction

*Utilization represents the actual production of the plant over the design production
* *Variation Order (Expansion to the original contract's scope)
***Due to early involvement of FM the number of VOs increased and the capital cost to meet the operation and maintenance's requirements

The above data shows that Case (B) has a higher number of VOs due to the introduction of FM early in the engineering phase. This increased the capital cost with 8,600,000 EGP, but with an analogous positive effect on both of:

1. The SWRO plant utilization with 11% more utilization in Case (B)
2. The reduction in electricity costs which reached 61%, noting that electricity costs form the biggest portion of the total lifecycle costs (Voutchkov. 2013)

5. ANALYSIS RESULTS

The analysis was aimed at quantifying the FM early involvement using reliability modeling as shown in the methodology. Fig. 4 illustrates a cumulative plot test for both cases A and B, the fixed slopes and low rise of case (A) indicates that the plant is deteriorating while the upward concave of case (B) which had the FM involved early at the engineering phase indicates an improvement of plant reliability. Also, Fig. 5 illustrates the eyeball analysis confirming to the above findings which having the time between failure frequencies rising more steeper in case (B) than of case (A) which indicates longer intervals of failure-free continuous operation.

To test for the presence of correlation in case (B), the Karl Parson's Coefficient of Correlation was calculated to be 0.8 which indicates a proportional increasing correlation as in Fig. 6 depicting the scatter plot. The MTBF (mean-time-between-failure) is calculated as the average of the two MTBF for both cases (A) and (B) and was calculated to be 250. Then reliability was calculated for both cases as below:

- $R_A(250)=0.322$ → Case (A)
- $R_B(250)= 0.409$ → Case (B)

From studying the above results FM limited involvement has improved the reliability of the plant by 27% at the average MTBF of both plants. In addition to the reliability improvement, electricity cost of producing one cubic meter of drinkable water was lowered by 38% in Case (B).

Table 2: Reliability modeling

t (hr)	**Case (A)** $R(t) = e^{-\lambda t}$	**Case (B)** $R(t) = e^{-\lambda t}$	**t (hr)**	**Case (A)** $R(t) = e^{-\lambda t}$	**Case (B)** $R(t) = e^{-\lambda t}$	**t (hr)**	**Case (A)** $R(t) = e^{-\lambda t}$	**Case (B)** $R(t) = e^{-\lambda t}$
0	1	1	240	0.3372	0.4244	480	0.1137	0.1801
10	0.9557	0.9649	250	0.3223	0.4095	490	0.1087	0.1738
20	0.9134	0.9311	260	0.308	0.3951	500	0.1039	0.1677
30	0.873	0.8984	270	0.2944	0.3813	510	0.0993	0.1618
40	0.8343	0.8669	280	0.2814	0.3679	520	0.0949	0.1561
50	0.7974	0.8365	290	0.2689	0.355	530	0.0907	0.1506
60	0.7621	0.8071	300	0.257	0.3425	540	0.0867	0.1454
70	0.7283	0.7788	310	0.2456	0.3305	550	0.0828	0.1403
80	0.6961	0.7515	320	0.2347	0.3189	560	0.0792	0.1353
90	0.6652	0.7251	330	0.2243	0.3077	570	0.0757	0.1306
100	0.6358	0.6997	340	0.2144	0.2969	580	0.0723	0.126
110	0.6076	0.6751	350	0.2049	0.2865	590	0.0691	0.1216
120	0.5807	0.6514	360	0.1958	0.2765	600	0.066	0.1173
130	0.555	0.6286	370	0.1872	0.2668	610	0.0631	0.1132
140	0.5304	0.6065	380	0.1789	0.2574	620	0.0603	0.1092
150	0.5069	0.5853	390	0.171	0.2484	630	0.0577	0.1054
160	0.4845	0.5647	400	0.1634	0.2397	640	0.0551	0.1017
170	0.463	0.5449	410	0.1562	0.2312	650	0.0527	0.0981
180	0.4425	0.5258	420	0.1492	0.2231	660	0.0503	0.0947
190	0.4229	0.5073	430	0.1426	0.2153	670	0.0481	0.0914
200	0.4042	0.4895	440	0.1363	0.2077	680	0.046	0.0882
210	0.3863	0.4724	450	0.1303	0.2005	690	0.0439	0.0851
220	0.3692	0.4558	460	0.1245	0.1934	700	0.042	0.0821
230	0.3529	0.4398	470	0.119	0.1866			

The above improvement in reliability is reflected on key component/design features of the RO process such as the below:

1. Higher durability of the high-pressure pump
2. Better materials for couplings and brine lines
3. Improved energy recovery
4. Added tolerance for changes in feed water properties
5. Added safety and protections for operation

The above was achieved through reviewing the design in the engineering phase and adding comments which relate to the operation, and further establishing design guidelines. The process was then evolving to a continuous feedback and improvements in the construction cycle. This called for issuing two VOs on the contract of Case (B) to avoid later increased costs throughout operation, and improve the efficiency and utilization of the plant.

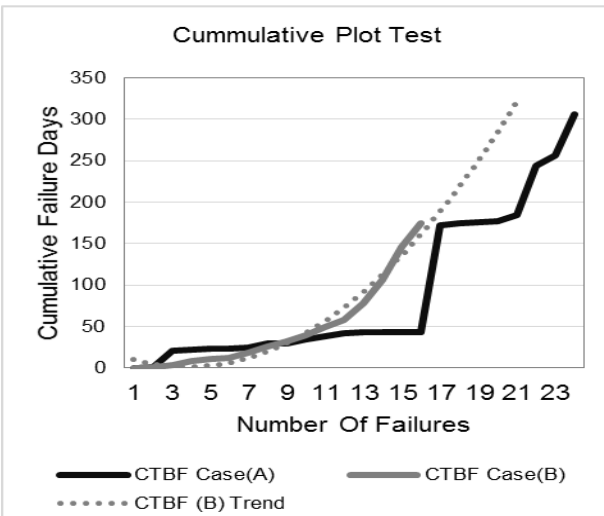

Fig. 4 Cumulative Plot Test

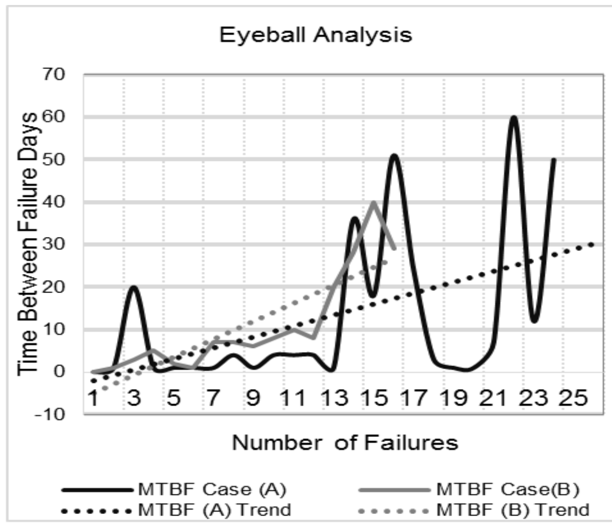

Fig. 5 Eye Ball Analysis

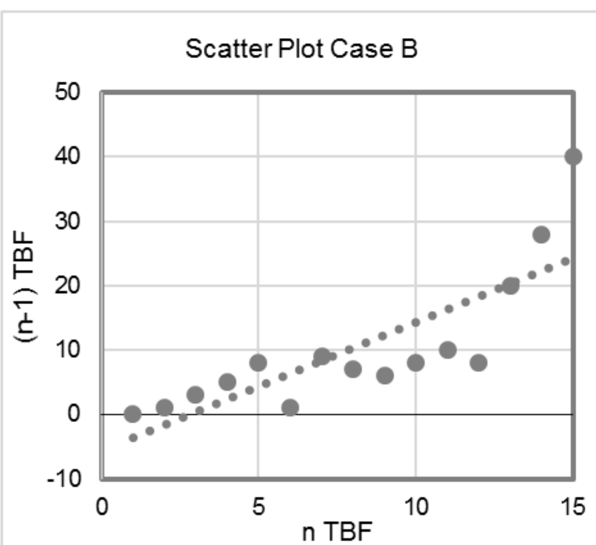

Fig. 6 Scatter Plot

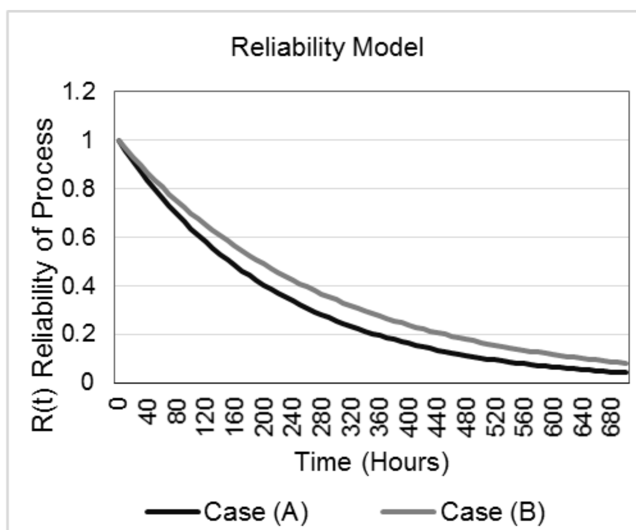

Fig. 7 Reliability Plot

6. CONCLUSION

The involvement of FM early at the engineering and projects stages reduces lifecycle costs and ensures a higher reliability. SWRO projects are capital investments that need to be continuously producing water, and the cases at hand showed a reliability boost of 27% when FM was involved early in the engineering and projects stages; while the involvement was minimal and without a resolute methodology but the effect remained profound, owing to the data, operation and management experience that are acquired by FM. Future researches should attempt to broaden the spectrum of FM involvement's effect on a variance of investments and projects, and establish a policy and protocols for FM early involvement in the project lifecycle.

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