METHODOLOGY FOR FAILURE ANALYSIS IN SERVICE PROCESSES THROUGH SIMULATION

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ABSTRACT

In this work we study the problem of determining the processes which cause delays in cementing services. Through the use of the Simio platform, a visual simulation model of basic cementing process is developed for different scenarios. Such scenarios are based on the number of orders of cementing services, the capacity of the cementing laboratory and the plant, as well as the number of resources available for the jobs. Multiple scenarios are tested, and their results help us to detect which part of the cementing process could cause delays in the completion of the jobs. Finally, based in these results, it is established the resources that the company needs, as well as the time required to complete a job.

Keywords: simulation, accomplished jobs, cementing process.

1. INTRODUCTION

A cementing job (CJ) is necessary to stabilize oil wells, preventing collapses and avoiding contamination of the surroundings. This job is required in every stage of the drilling well and is even necessary to close the well when the oil has been extracted from it.

The cementing service process (CSP) is complex because requires time, personal experience and materials with high costs. Besides, when an unexpected CJ is ordered a technical planning is needed. First, it is important to design a pumping schedule which includes a tuned cement slurry, specific personal and equipment. Every oil well is different. There may be similitude in temperature, gradient, geology between wells, but never is exactly the same. Then it should be designed a tuned job for each oil well.

An ordinary cementing service needs as equipment one batch mixer truck, one high pressure unit and one transporter of cement. On the other hand, the crew needed includes one supervisor, three unit operators, three assistants and one engineer. Sometimes the oil well cementing service requires a large volume of cement slurry, and batch spacers which need high quantity of water and additives for its preparation, and as consequence, a greater number of equipment and personal is required. In general, the number of equipments for each job has to be planned before.

Ordinarily, the costs of operations are high and a possible failure could cause an elevated economical impact. In fact, it is common to have failures because of delays, human errors, equipment failures, etc. All failures produce a cost penalization and a possible unsatisfied customer, whose effects are difficult to measure.

Sometimes the demand of CJ is high, and exceeds the company's capacity, and when the company accepts more jobs than those they can attend, a failure comes due to the lack of enough human or material resources. It shows the importance of a policy response to different demands in cementing services, avoiding high cost due to failure when a wrong decision is taken. The full knowledge of the capacities of the company in different scenarios is then relevant to formulate this response policy, and this work could help to clarify this knowledge. Moreover, this work could serve to detect which part of the process should be improved when forecasts indicates a possible increase in the demand of CJ.

On the other hand, there exists another kind of service offered in CSP called Pumping Jobs (PJ). This PJ, consist in the rent of a high unit pressure to the customer. This type of job does no need design either the use of the plant but, it impacts on the disposition of the units for CJ because PJ requires much time.

In this paper, Simio simulation is used to analyze different stages considering two kind of demands, urgent and planned, for two kind of jobs, CJ and PJ, in order to determine the process that causes more queuing issues, making us able optimize that result and obtain a policy response.

2. CEMENTING PROCESS

The oil well cementing services uses a complex process to deliver a service. However, in this paper we are going to take the basic process of an ordinary CJ and PJ.

Cementing jobs consist firstly in a laboratory design of the cement slurry according to the oil well characteristics. The corresponding instructions of the mix of cement and additives are then sent to the cementing plant. A sample of this cement is inspected in the laboratory before the cement mix be transported to the oil well, where a high pressure unit (UAP) finish the work pumping the cement into the oil well. On the other hand a PJ provides an UAP to the customer, without the previous stages of design and mixing the cement.

In both kind of CSP, we could have planned and urgent orders. The former ones are regular and planned well in advance. The last ones, occurs without previous notification, but can be estimated the average of them by studying the historical data.

3. FAILURE ANALYSIS

Commonly, failures give evidences, whose analysis exposes deficiencies in the system. They could have different origins, such as manufacture, materials selection, and design or operation procedures. When that knowledge is obtained, it is possible to prevent or minimize failures. In any kind of services, it is important to reach the client expectations; however, there are also failures whose occurrence is important to maintain under control because they impact directly on the costs. Nowadays, the majority of the approaches of failure analysis are focused on products and not in services.

Failures in services are more difficult to treat due to the impossibility of make physical tests when a failure occurs. The present work could serve as an alternative method to identify origins of failures in services by making use of simulation analysis.

3.1. Proposed Methodology

The methodology that we propose to analyze failures in services is schematically represented in Fig. 1. Some of the steps are explained below.

Determine failures: Determine all kind of failures that could occur in the system.

Determine causes of failures: The causes of each failure are determined separately.

Hierarchy of failures: In this methodology the analysis is systemic, so it is important to identify those failures that are critical in the system. For determine this hierarchy we can use quantity or quality criteria.

Simulation of complete process: This step is necessary for complex systems. The methodology for failure analysis proposed in this paper should accomplish the simulation methodology of reference (Mussellman 1992; Sadowski 1989).

Obtain the set of critical causes: The objective of this methodology is to determine the set of critical causes. Once identified these critical elements, we can minimize failures by means of operational research procedures.

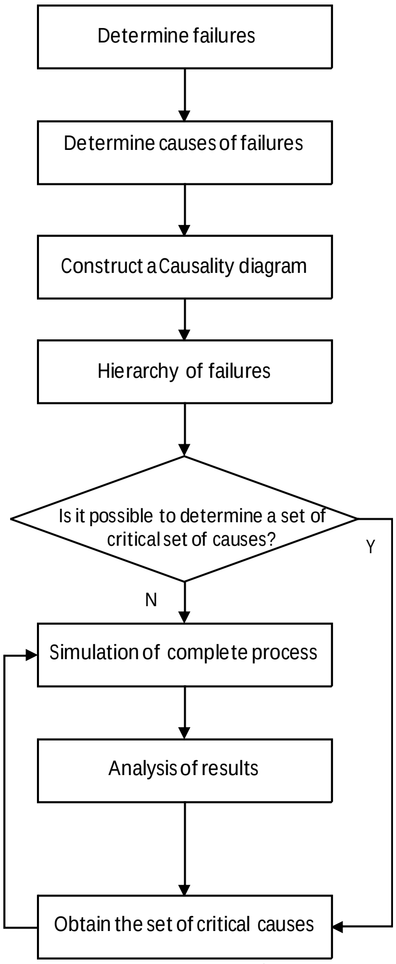

Figure 1: Proposed Methodology for Failure Analysis in Cementing Services Processes.

3.2. Causality Analysis

In this paper, the application of the methodology is applied to the cementing service process (CSP).

The most important failures of CSP are shown in Table 1. The critical criterion is based in the payment of a penalty charge for no productive time. In the case of CSP every hour the customer waits for the job has a certain price. The price is established in the initial contract. Also, CSP has failures which do not generate penalty charge.

Table 1: Classification of failures

Failure type		Critical criterion		
		The job is done?	The job is pay?	Penalty is charged?
Unavailability of equipment		Y/N	Y/N	Y
Unavailability of personal		Y/N	Y/N	Y
Oil Well Tools Failure		Y	Y	Y
Cementing Equipment Failure		Y/N	Y/N	Y/N
Personal Failure		Y	Y	N
Personal Failure		Y	Y	N
Cementing Equipment Failure		Y	Y	N
Customer Dissatisfaction		Y	Y	N
Cement Unconsistant		Y	N	Y/N
Others	Lost on the road	Y	Y	Y
	Later called	Y	Y	N
	Time offset	Y	Y	Y
	Forgot additive	Y	Y	Y
	Affectation owners	Y	Y	N

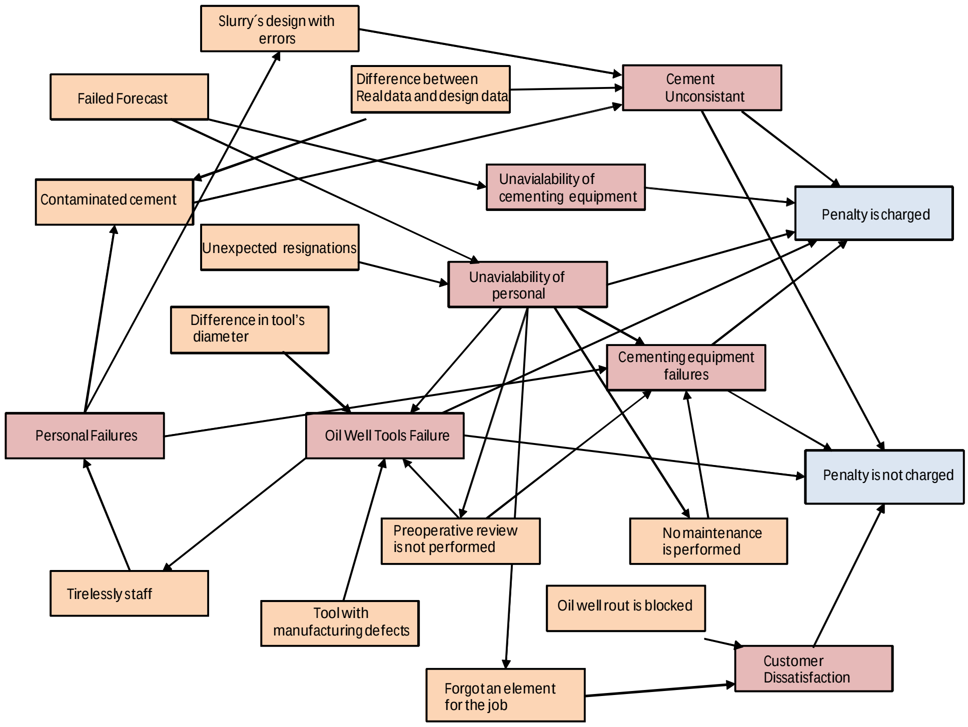

Figure 2: Causality diagram for cementing services failures

Now, we need to determine the causes of every failure type, in separately form. For this analysis we have used the questions suggested by De Castro to get objective information (De Castro, 2004).
A systematic failure analysis is fundamental to prevent or avoid future damages, being important to determine the causes of each failure and the relations between them, which are represented by means of the causality diagram (Guo Li, 2008). In Fig. 2 is illustrated the causality diagram for the CSP, where all the failures are related to the causes. This analysis can provide insights about the problem that we are studying. However, without data of the influence weights in the edges of the network, it is hard to determine the set of critical causes of failures.

4. USING SIMIO

Since the causality diagram is not enough for establish the set of causes, the use of other techniques for get information is needed. Simio is a simulation modeling framework based on intelligent objects (Pedgen, 2011). In this paper, the intelligent objects are built for modeling every step of the CSP described in section 2. Particularly, we use Simio to identify the part of the process which causes queues. It is important to detect possible issues through simulation, because when the problematic part of the process is clearly identified, we can improve the system.

4.1. Simulation of CSP in Simio

The use of simulation can provide a lot of information about the process. We use Simio to simulate the CSP, and analyze how the unavailability of equipment or personal contributes to delays in the completion of the jobs.

The conceptual model of simulation that we are going to use is schematically represented in figure 3 for the processes of cementing jobs (CJ) and pump jobs (PJ). As can be noticed, the CJ requires a previous stage of cement design before the work can be sent to the oil well.

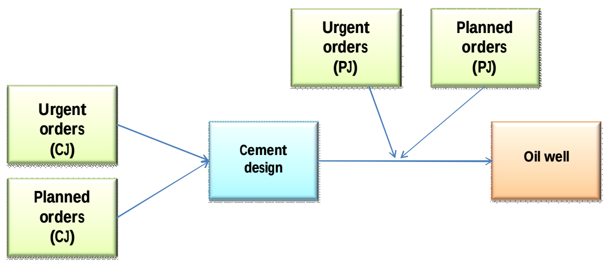

Figure 3: Conceptual simulation model of CSP.

The cement design consists in the series of steps represented in figure 4. The laboratory technician receive the order and prepare the design to be sent to the consistmeters. If some required parameters are not accomplished, the process is repeated by adjusting the design. When the design is ready, it is sent to the plant where employee mix cement and additives in the mix tank in accordance to the laboratory instructions. Then a sample of the mixed cement is sent to the laboratory for quality control. If the quality control is passed, the cement is ready for the oil well, else, the laboratory technician adjust the batch sending instructions to the plant employee and again a sample is send to quality control. When the cement fails the quality control two times, the process is repeated from the beginning by making a new design.

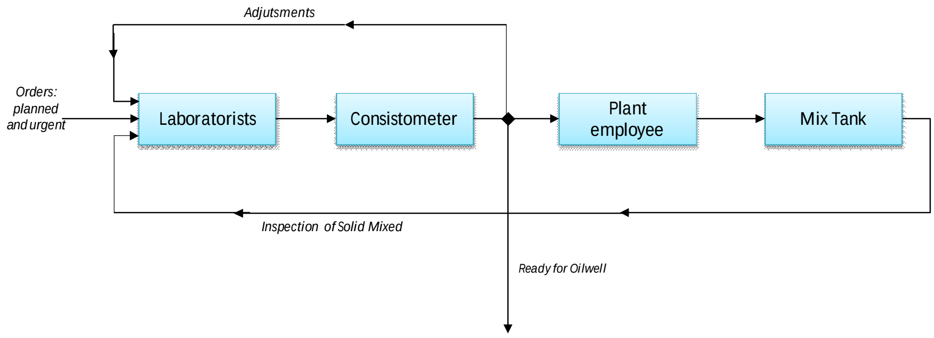

Figure 4: The process of cement design

In Fig. 5 is shown the whole CSP used in the Simio environment. The next parameters were considered in our model:

Frequency of planned CJ and *PJ*: Both considered as constant in time.

Frequency of urgent CJ and *PJ*: It is assumed that they are generated following an exponential probability behavior.

Capacity of Laboratory technician, Consistometers, Plant Employee, Mix Tank and UAP: Indicate how many orders can be process at the same time.

Processing times of Laboratorist, Consistometers, Plant Employee and Mix Tank: Indicate time necessary to process the order. We take these values as fixed.

Processing time of UAP: Time necessary to process an order in the high pressure unit. We consider that this value could be different for CJ and PJ.

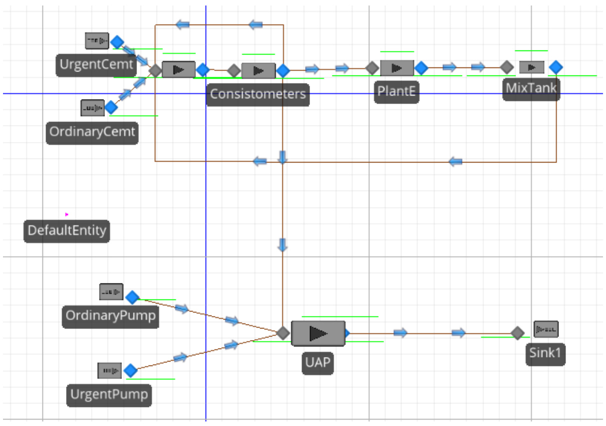

Figure 5: Model of CSP in Simio

Probability of fail a design: Assigns a probability for the order to be adjusted in its design.

Probability of failed inspection: Assign a probability for the cement mix to be adjusted.

Probability of fail in adjust batch: When the sample from the plant fails the quality control, gives the probability that the adjustment of the cement mix be failed.

Probability of redesign: Assign a probability of failure the second quality control inspection, and then, start over the process.

Additionally, each step of the system processes first the oldest orders with the purpose of finish them as soon as possible. In the case of the UAP process, CJ have priority over PJ. For this simulation, we will use the parameters given in table 2.

The objective of this simulation is to know:

- Delivery times for CJ and PJ,
- Total Waiting times for each type of orders
- Relationship of equipment number and time of compliance of service.
- Rates of adjustment and redesign

4.2. Verification and Validation of Model

The verification of the simulation model consisted in check its logic behavior according to the set values (Kleijnen, 1995). The most important proofs we did are explained below:

Verification of model structure: Visually, the simulation model corresponds to the real system. In this case, the model does not contradict the CSP behavior.

Parameters verification: In this point, we review that the proposed parameters values were correctly load into the model.

Extreme conditions test: In this point we proof the effectiveness of system decision-making when arrives a lot of orders with different dates, such that the priority values should be executed according to the hierarchy process.

Behavior proofs: The first instance simulated, predicted in correct form the results that we expected, based on the probability values set. Besides, we developed a sensitivity analysis varying the values of the parameters in order to get suitable results.

Table 2: Parameters used for the simulation

Parameter	Value
Frequency of planned CJ	1 per day
Frequency of planned PJ	1 per 2 days
Frequency of urgent CJ	1 per 2 days
Frequency of urgent PJ	1 per day
Capacity of Laboratorists	1
Capacity of Consistometers	1
Capacity of Plant Employee	1
Capacity of Mix Tank	1
Capacity of UAP	7
Processing time of Laboratorist	1 hour
Processing time of Consistometer	1.5 hours
Processing time of Plant Employee	45 minutes
Processing time of Mix Tank	1 hour
Processing time of UAP (CJ)	Random(24-48) hours
Processing time of UAP (PJ)	Random(24-72) hours
Probability of fail a design (First Time)	50%
Probability of fail a design (No First Time)	20%
Probability of failed inspection	10%
Probability of fail in adjust batch	5%
Probability of redesign	5%

Once the verification is done, we have to validate the simulation model (Kleijnen, 1995). The validation of the model proposed in this paper is based on real-world data. The historical data number of CJ and PJ has a mean of 94 orders requested per month. Our model generates around 90 orders per month. On the other hand, the results of the completion times per order are in validation by an expert.

4.3. Results

Through the simulation, we can understand part of the dynamics of the processes. In Figure 6 is shown the cumulative fraction of CJ as function of its completion time for the parameters of Table 2. As can be seen, 50% of CJ become complete in around 50 hours, and above 60 hours an important quantity of the CJ have been completed.

As a first part of the analysis we studied the delivery time for every order when the capacity of UAP is varied. In Table 3 are the total waiting times for deliver 50%, 90% and 100% of the orders arrived in the set period. Notice that the time is reduced when the number of UAP is increased. However this reduction of time is no longer relevant when the number of UAP is greater than seven. The opposite occurs when the number of UAP is five or less, indicating that the queues are out of control, and then, at least there should be six UAP units working.

Table 3: Total Completion Time for CJ and PJ (in hours)

No. UAP	CJ			PJ		
	50%	90%	100%	50%	90%	100%
5	54	68	96	392	812	1160
6	49	62	83	55	90	174
7	47	57	80	50	70	122
8	46	56	80	48	68	88
9	45	56	76	48	67	74
10	45	55	75	48	66	74

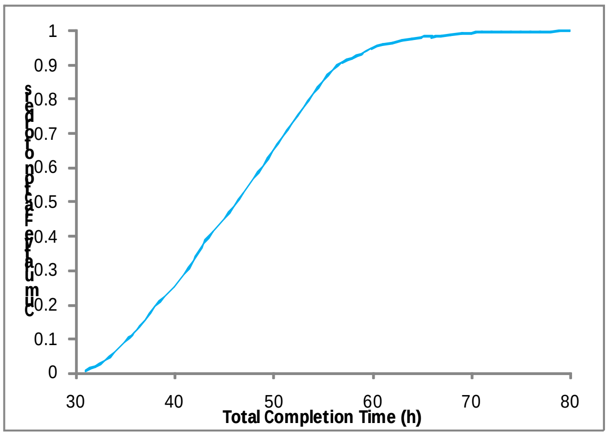

Figure 6: Cumulative fraction of CJ as function of its completion time.

Another critical equipment to be considered as a variable of the failure system is the quantity of Consistometers. For this simulation we set seven UAP and vary the number of consistometer and the results of the completion time are shown in table 4. We can see that the variation between one and two consistometers produce not noticeable difference in the total completion time. Moreover, we do not obtain any benefit by having three consistometers instead of two.

In the simulation results, we got 55.34 % of CJ with some adjustment, and 0.46 % orders were started over and are the cause of most of the delays in completion times.

Table 4: Total Completion Time for CJ (in hours))

No. Consistometers	CJ		
	50%	90%	100%
1	47	57	80
2	45	56	83
3	45	56	83

5. CONCLUSIONS

In this work we have analyzed how the capacity of resources can generate delays in the completion time of cementing and pumping jobs of CSP. For the frequencies jobs showed in table 2, we have found that the number of UAP should be more than seven, and the number of consistometers should not be greater than two. Moreover, the company should promise to complete a CJ in at least 57 hours, and a PJ in at least 70 hours; in this way, the company can assurance that more than 90% of the jobs will be delivered on time, avoiding the penalty charge for no productive time in most cases. Beyond this analysis, it is important to consider the costs and profits involved in CSP, as well as how the promised time of completion impacts on the customer decision of require the company services over other competitors. These analyses are currently under development.

In summary, we believe that the use of simulation is a very efficient way of obtaining valuable information in order to plan a better response policy of a company.

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REFERENCES

Alamilla J.L., Sosa E., Sánchez-Magaña C.A., Andrade-Valencia R., Contreras A., 2013, Failure analysis and mechanical performance of an oil pipeline. *Materials and Design,* 50, 766 – 773.

Brown, J.E., 2009. Identifying cost reduction and performance improvement opportunities through simulation. *Proceedings of the 2009 Winter Simulation Conference*, 2145-2153.

De Castro P., Fernandes.A.A. 2004. Methodologies for failure analysis: a critical survey. *Materials and Design,* 25, 117-123

Guo L., Jianmin G., Fumin C., 2008. Construction of Causality Diagram Model for Diagnostics. *IEEE Reliability and Maintainability Symposium.* 28-31 Jan., Las Vegas, NV 97-102.

Hung, J.Y., Park, N.J., George, K.M., Park, N., 2013. Modeling and Analysis of Repair and Maintenance Processes in Fault Tolerance Systems. *IEEE International Symposium on Defect and Fault Tolerance in VLSI and Nanotechnology Systems (DFT)*, 2-4 Oct. 2013, New York City, NY.261-265.

Kleijnen J., 1995. Verification and Validation of simulation models. *European Journal of Operational Research,* 82, 145-162.

Kumbale, M., Hardiman, R., Makarov, Y., 2008. A metohodology for simulating power system vulnerability to cascading failures in the steady state. *European Transactions on Electrical Power*, 18, 802-808.

Mussellman, K.J. (1992). Conducting a Successful Simulation Project. *Proceedings of the 1992 Winter Simulation Conference,* 115-121.

Pasman, H.J., Knegtering, B., Rogers, W.J., 2013. A holistic approach to control process safety risks: Possible ways forward. *Reliability Engineering and System Safety,* 117, 21-29.

Pegden, C.D., Sturrock, L.L.C., 2011. Introduction to Simio. *Proceedings of the 2011 Winter Simulation Conference,* 11-14 Dec, Phoenix, AZ., 29-38.

Rossmanith HP. Structural failures – liability, learning from failures, technical insurance and legal consequences. Invited lecture 5th specia1 chair AIB-Vin cotte 1995, Vrije Universiteit Brussel, 21 February 1995

Sadowski. R.P. (1989). The Simulation Process: Avoiding the Problems and Pitfalls. Proceedings of the 1989 Winter Simulation Conference (Ed.: MacNair, Musselman, and Heldelberger) Washington, D.C., pp. 72-79

Zhang, K., Wu, R., Ning, J., Zhang, X., Du, H., 2011. Using Simio for Wartime Casualty Treatment Simulation. *IEEE*, 322-325.

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