# SIMULATION OF QA/QC IMPACT ON ONSHORE JACKET FABRICATION PRODUCTIVITY

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## ABSTRACT

Inadequate contract documents in earlier project time or unforeseeable factors during the project performance cause construction dispute. These factors impact project cost and duration as well as causing inconsequence to one or more of the project parties. There are large number of quality assurance / quality control (QA/QC) onshore activities in the fabrication of an offshore fixed steel jackets and platforms. This, certainly, interrupts production time and might cause delays that discomfort all project parties. Therefore, current paper models the impact of QA/QC on an onshore fixed steel jacket fabrication using Monte Carlo simulation. A simulation model is developed with and without QA/QC to illustrate parties' responsibilities and show its impact on productivity. The developed model is applied to a case study in order to analyze the QA/QC effect. Results show that the QA/QC enlarges project duration by almost 20%. Sensitivity analysis is carried out to show the model's sensitivity to input changes and look for alternate solutions to reduce QA/QC durations. Remedial solutions are employed and analyzed to alleviate extra project disputes. Current research is relevant to fabrication companies, consultants, and owners of fixed steel jackets.

## KEY WORDS

Fixed Steel Jackets, QA/QC, Simulation, Project Parties Disputes, Fabrication

## INTRODUCTION

Construction industry is one of the largest businesses worldwide. Owners and contractors are the major players in this field. Since the start of construction project until the end, both parties are looking for better and accurate ways of productivity calculation and consequently, accurate expenses. During contract execution, both parties know their rights and responsibilities. Contractors have to accomplish the project based on the performance criteria that are set in the plans and specifications. Owners and/or owner's representatives have to

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inspect the project during execution to be sure that it is accomplished according to specification. Usually decision makers don't calculate the impact of such inspection on the total project duration and productivity.

As an example of large construction projects is the fixed jacket-welded platform. The jacket is a welded frame, which is designed to serve as a support for a platform in the sea. It consists of vertical piles supported by lateral bracing to carry out horizontal forces of water and waves. For such structures, there is limited research work particularly in productivity assessment of jacket fabrication process.

Therefore, current research aims at designing a fixed steel jacket fabrication productivity model using simulation, experimenting with such model with and without QA/QC activities; and measuring the QA/QC activities impact on production process.

## QUALITY ASSURANCE / CONTROL (QA/QC) BACKGROUND

The three major control parameters for construction projects are quality, time, and cost. Up to 1960s, quality was the most important element; however, time and cost control were introduced later (O'Brien, 1991). Recently, in the construction industry, quality has to be measured by most project parties. In the other words, every body is responsible for quality. Contractor has to do the best to satisfy contractual quality criteria; otherwise, its business might face serious problems.

In oil industry, specifically offshore oil, the value of investment and importance of projects persuade the industry to develop quality control and assurance systems. Quality control (QC) procedures in the oil industry are more complicated than that of other industries (O'Brien, 1991). Quality assurance (QA) includes technical and operational activities as well as elements that satisfy project performance (O'Brien, 1991). The QC is part of QA process including activities related to the work inspection. Contractors who are involved in gas and oil projects have developed their own QA plans, which are usually required by the owner. This QA plans establish the QA program, which is intended to control quality aspects of gas and oil projects. In the oil industry, general contractor usually provides inspection and the owner have a tendency to view the inspection activities and results. O'Brien (1991) reported that the inspector must closely follow the progress of each fabrication phase, observe, test, and inspect material, equipment, work-in-progress, and work-completed for compliance and quality. Most likely this will take time and might cause conflicts and schedule interruption. The more QA/QC activities, the more interruption will be and the more conflicts will occur. The QA/QC results might favor rework, which increase delays and increase potential disputes among different project parties. For such reasons, the contractor is positively promoted to plan for these activities and predict their expected results in order to reduce interruptions and disputes.

Simulation technique can be applied to the modeling of jacket fabrication in order to study different combinations of resources and impact of inspection procedures on the fabrication process. MicroCYCLONE modeling and programming technique is a potential candidate to simulate this process. The elements of MicroCYCLONE (Figure 1), originally developed by Halpin in 1973, are used to model and simulate the fabrication process.

MicroCYCLONE is a simple and powerful tool for construction process planning, as demonstrated by many researchers (Zayed and Halpin, 2001).

## CONTRACTUAL RELATIONSHIP AND MODEL DEVELOPMENT

Figure 2 shows the contractual relationship among different contractual parties. In jacket fabrication projects, usually, general contractor is responsible for fabrication contract in front of oil and gas company, which will be a government or private company. Moreover, general contractor is responsible for the entire oil field, drilling, onshore facilities, offshore facilities, pipelines, refineries, etc. On the other hand, jacket fabrication contract, usually, consists of fabrication activates. The contractor has to prepare labor crews and equipments that are required for fabrication. In addition, he/she has to assign engineering and QA/QC departments. Material, pipes and steel plate's procurement are the owner responsibility. Owner has specific QA/QC inspectors; however, the fabricator is responsible for submit quality control reports to the owner's QA/QC. The fabricator's engineering department has to prepare shop-drawings and the owner representative has to proofread them.

This contractual relationship has to be considered when scheduling fabrication projects because it greatly affects project duration. If the contractor's QA/QC or engineering departments do not perform their tasks as planned, obviously, the activities' productivity will be reduced, which will be interpreted into losses. On the other hand, owner or his/her representative is responsible for approving the documents and work performed. If he/she has no enough representatives and staff in the fabrication site, the QA/QC activities will take longer time and might delay the project. Consequently, the influence of their actions in the fabrication process has to be evaluated and analyzed.

After identifying the construction algorithm or phases of jacket fabrication, a simulation model can be designed using MicroCYCLONE simulation package (Halpin and Riggs, 1992). The MicroCYCLONE elements that are used in modeling the construction of steel jacket fabrication are shown in Figure 1. Based on these elements, a model is developed to represent the jacket fabrication considering the QA/QC activities as shown in Figure 3. It shows the fabrication of legs, bracing, and mainframe in addition to roll-up activity. It also shows the QA/QC and redoing activities and their relation to other fabrication activities.

## CASE STUDY

To determine the productivity of steel jacket fabrication in yard and impact of QA/QC activities on total system productivity, consider the development and analyses of the steel working sequence on a jacket of wellhead platform as shown in current case study. It includes four legs jackets in Abouzar project, 75 Km to the west of Kharq Island, Persian Gulf, Iran. The client was National Iranian Oil Company (NIOC); it started in October 1996 and finished in December 2001. Based on the contract, contractor had to operate five wellhead platforms, namely A15, A16, A17, A18, and A19. The wellhead platform consists of four legs steel jacket. According to the scope of work, contractor had to do technical inspection, detail engineering, procurement, fabrication, transportation, installation, pre-commissioning, and commissioning for both of decks and jackets in five platforms. The process of steel work, cutting, fit-up and welding for all jackets are similar.

## FABRICATION PROCEDURE

The fabrication procedure of wellhead platform jacket is shown in Figure 4. The complete fabrication process consists of seven main steps. After the installation of saddles, surveying, and installation of benchmarks, the first step starts by fabricating legs elements. Then, the second main step starts by fabricating rows A and row B. The third step will be roll-up activity when row A and B are completed. In this step, usually a crane is doing roll-up activity in one day in which the contractor is using temporary braces to keep the vertical rows stable. Next step is fabricating bottom row (row 2) while the mainframe elements are pre-fabricated in shop and then, carried out to the yard for installation in the jacket. After completing roll-up procedure, prefabricated frames can be installed. The braces in upper row are installed and the interior braces as well as the frame connections are established.

## SIMULATION MODEL APPLICATION TO CASE STUDY

Activity durations are estimated and embedded into the MicroCYCLONE model to start simulation. The input data include: cutting, fitting-up, welding, roll-up and transportation times as shown in Table 1. It shows the general project steps that are considered in the simulation model in addition to the duration of each activity. Welding time is determined based on a crew of 4 welders where fit-up time is based on a crew of 8 pipe fitters. Various

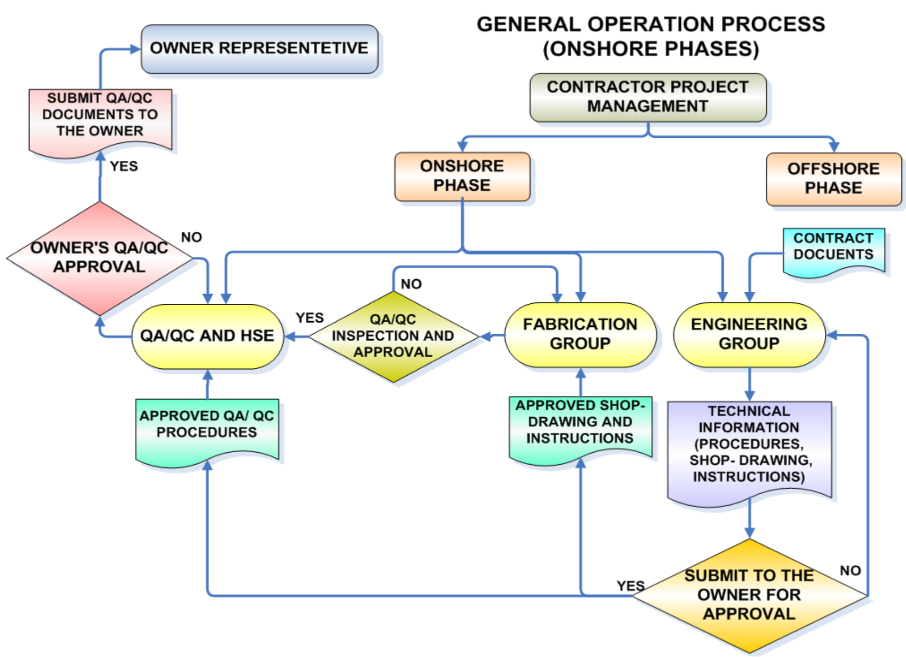
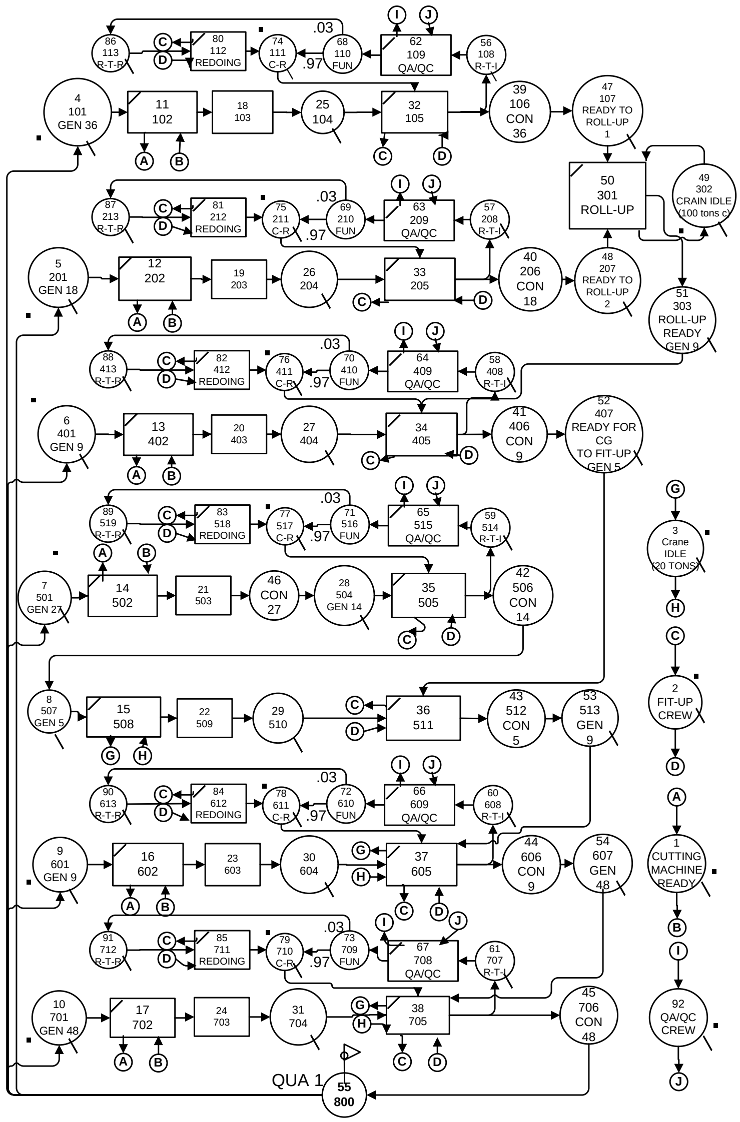



Figure 2: General Operation Process for Onshore Phases




**LEGEND**

1. **Legs fabrication in yard**
101 Legs pipes available
102 Cutting Legs
103 Legs carry to the yard
104 Legs ready to fit-up
105 Legs fit-up and weld

2. **Row A & B fabrication in yard**
201 Braces pipes available
202 Cutting Braces
203 Braces carry to the yard
204 Braces ready to fit-up
205 Braces fit-up and weld

3. **Roll-Up and temporary braces**
301 Roll-Up
302 Cruller cranes idle

4. **Row 2 fabrications in yard**
401 Braces pipes available
402 Cutting Braces
403 Braces carry to the yard
404 Braces ready to fit-up
405 Braces fit-up and weld

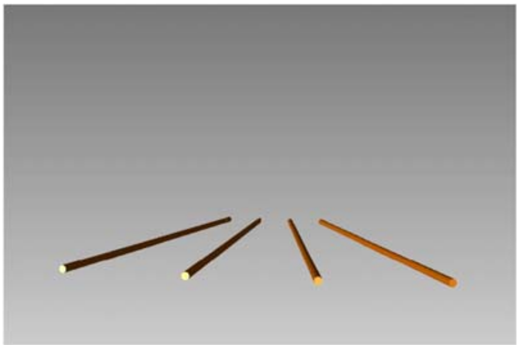
5. **Mainframe prefabrication and installation**
501 Mainframe pipes available
502 Cutting Mainframe pipes
503 Mainframe elements carry in shop
504 Mainframe elements ready to pre fabrication
505 Mainframe elements fit-up and weld in shop
507 Prefabricated Mainframe ready to carry to yard
508 Prefabricated Mainframe lifting
509 Prefabricated Mainframe carry to yard
510 Prefabricated Mainframe ready to assembling
511 Prefabricated Mainframe assembling in yard

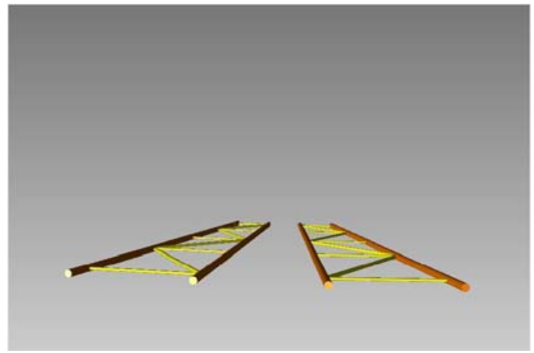
6. **Row 1 fabrication in yard**
601 Braces pipes available
602 Cutting Braces
603 Braces carry to the yard
604 Braces ready to fit-up
605 Braces fit-up and weld

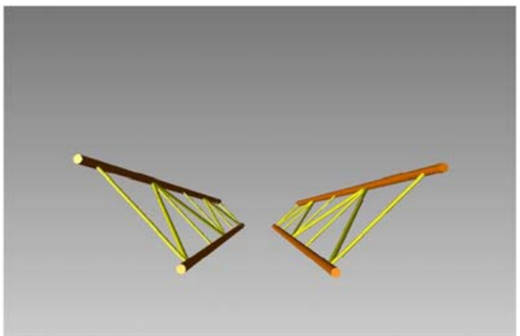
7. **Diagonal braces in mainframe fabrication**
701 Braces pipes available
702 Cutting Braces
703 Braces carry to the yard
704 Braces ready to fit-up
705 Braces fit-up and weld

Figure 3: MicroCYCLONE jacket fabrication model with application of QA/QC

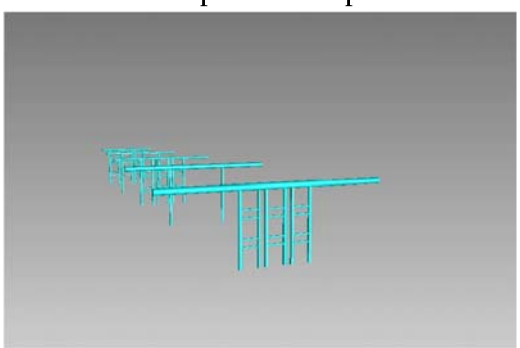
cutting times are used in the designed simulation model based on supplier's automated cutting machine information. Roll-up time is allocated based on project roll-up duration (one day). In typical fabrication procedure, QA/QC is parallel to the fabrication activities. Usually, inspectors might reject a percentage of fabrication activities (3% of fit-up and welded elements are rejected and fabricator had to redo them). Obviously, inaccurate fabrication increases the total project duration. Therefore, current developed model illustrates the influence of contractor errors on project. The MicroCYCLONE package is used to simulate with the developed model shown in Figure 3. Sensitivity analysis is used to estimate productivity based upon various QA/QC stoppage and rework times. Welding times depend mainly on various welding lengths, procedures, and type of connection. The results of simulation as well as sensitivity analysis are shown in Tables 2 and 3. Table 2 shows the


Step 1. Legs fabrication in yard

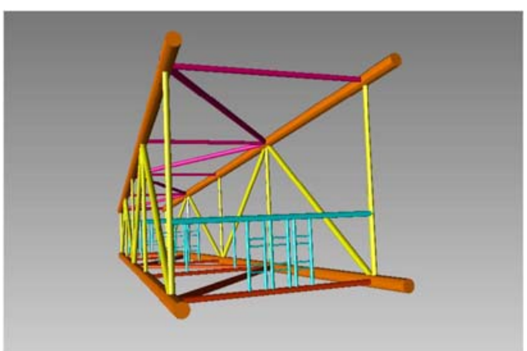

Step 2. Row A & B fabrication


Step 3. Roll-Up


Step 4. Row 2 fabrications


Step 5a. Mainframe prefabrication


Step 5b. Mainframe carry to yard and installation


Step 6. Row 1 fabrication in yard


Step 7. Mainframe diagonal braces fabrication (completed jacket)

Figure 4: Fabrication steps for wellhead platform jacket.

Table 1: General project steps and duration considering the simulation model

| Step | Description | Average Cutting Time (min) | Average Welding & Rolling-up time (min) |
|---|---|---|---|
| 1 | Legs fabrication in yard | 28 | 360 |
| 2 | Roll-up | One Day | |
| 3 | Row A & B fabrication in yard | 11 | 360 |
| 4 | Row 2 fabrication in yard | 11 | 359 |
| 5 | Mainframe prefabrication in shop | 6 | 138 |
| 6 | Row 1 fabrication in yard | 11 | 336 |
| 7 | Diagonal braces in mainframe fabrication | 7 | 141 |

QA/QC stoppage times and their associated productivity in jacket/hr and day/jacket. It further shows that productivity at 0% stoppages is 0.0099 jacket/hr and 101 day/jacket (assuming 44 working hours per week). On the other hand, if the jacket is fabricated with 30% stoppages in each activity (caused by inspection), productivity will be 0.0088 jacket/hr and 114 day/jacket. Figures 5 and 6 show the relation between productivity (jacket/hr and day/jacket) and stoppage times enforced by inspection. Similarly, Table 3 shows productivity analysis using different rework percentages. If a jacket is fabricated with 15% redoing, productivity will be 0.0091 jacket/hr and 110 day/jacket. Figures 7 and 8 also show the relation between productivity (jacket/hr and day/jacket) and percent of rework. It is obvious that the developed curves for QA/QC stoppage time and fabricator rework percent are deemed beneficial to practitioners in the fabrication and offshore industries. These curves can further be used to plan offshore projects efficiently. They enable experts to optimally schedule fabrication operation in a specific project and within various projects. Also, these results help to release disputes and contractual conflicts between fabricator, general contractor and owner, effectively.

| | Stoppages vs. activity duration (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Fabrication Duration (days) | 101 | 109 | 110 | 114 | 115 | 120 | 124 | 132 | 137 | 140 | 146 |
| Fabrication Productivity (jacket/day) | 0.0099 | 0.0092 | 0.0091 | 0.0088 | 0.0087 | 0.0083 | 0.0080 | 0.0076 | 0.0073 | 0.0071 | 0.0068 |

Table 2: Productivity values vs. different QA/QC stoppage times (3% rework)

| | Fabricator rework (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
| Fabrication Duration (days) | 99 | 101 | 105 | 107 | 109 | 110 | 113 | 116 | 121 | 124 | 124 |
| Fabrication Productivity (jacket/day) | 0.0101 | 0.0099 | 0.0095 | 0.0094 | 0.0092 | 0.0091 | 0.0089 | 0.0086 | 0.0083 | 0.0081 | 0.0081 |

Table 3: Productivity values vs. different percentages of fabricator rework

## SIMULATION MODEL VALIDATION

Data was collected from projects considering fabrication time and redoing percentage. According to the contract specification, fabricator allowance (3% redoing), and case study. The QA/QC staff was adequate and did not cause delays. The actual duration for five similar jackets was 6 months with 20 days difference in starting each one. The actual jacket duration was 100 days with a productivity of 0.0099 jacket/hr. The model output for similar jacket is 101 day/jacket as shown in Table 2 and Figures 5 and 6. Therefore, the model is 100/101 = 99% valid. This figure shows the robustness of the developed model in representing jacket fabrication process.

## CONCLUSION AND FURTHER STUDIES

Current research designs a productivity model for steel jacket fabrication using simulation. This model considers several factors that affect productivity, such as fabrication procedures, cutting time, fit-up and welding, QA/QC stoppage times, redoing percentages, and role–up duration. Several charts are developed to determine productivity of fabrication considering different QA/QC stoppages, and redoing percentages. The model is validated and shows robust results. The developed model is essential to decision makers, contract managers, practitioners, and researchers because it provides practitioners with dispute resolution and decision making tools for their fabrication project. On the other hand, it provides researchers with a simulation model that is flexible enough to modify and add more features to it in order to enhance its capabilities.

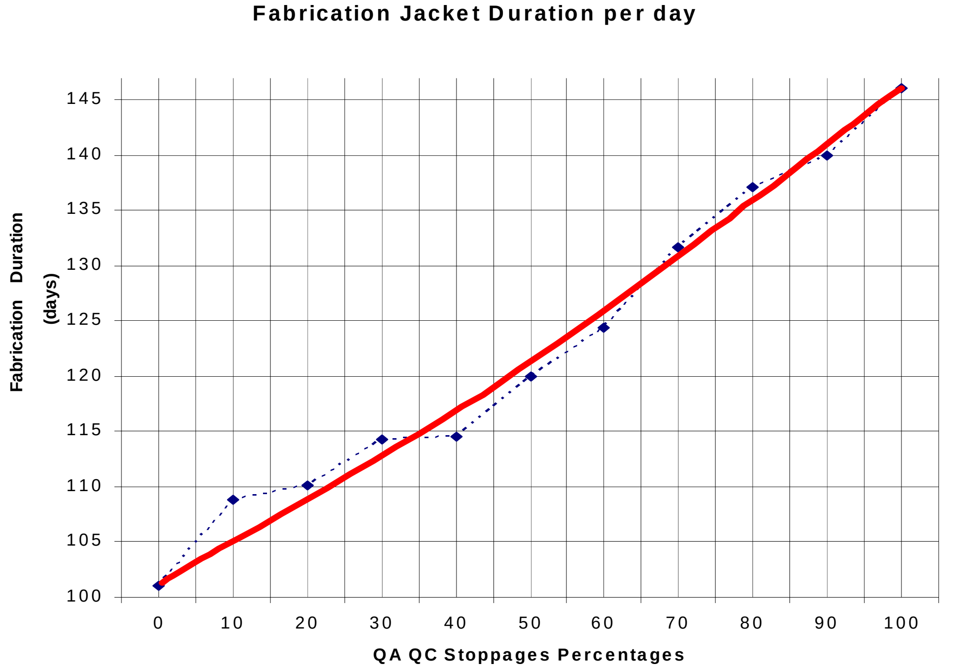



Figure 5: Fabrication jacket duration per days considering QA/QC influence

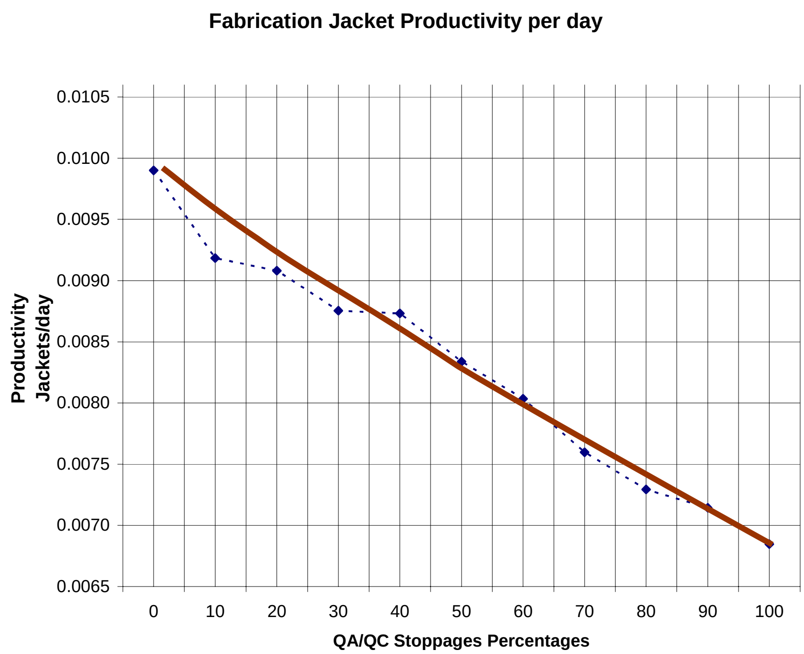



Figure 6: Jacket fabrication productivity considering fabricator errors

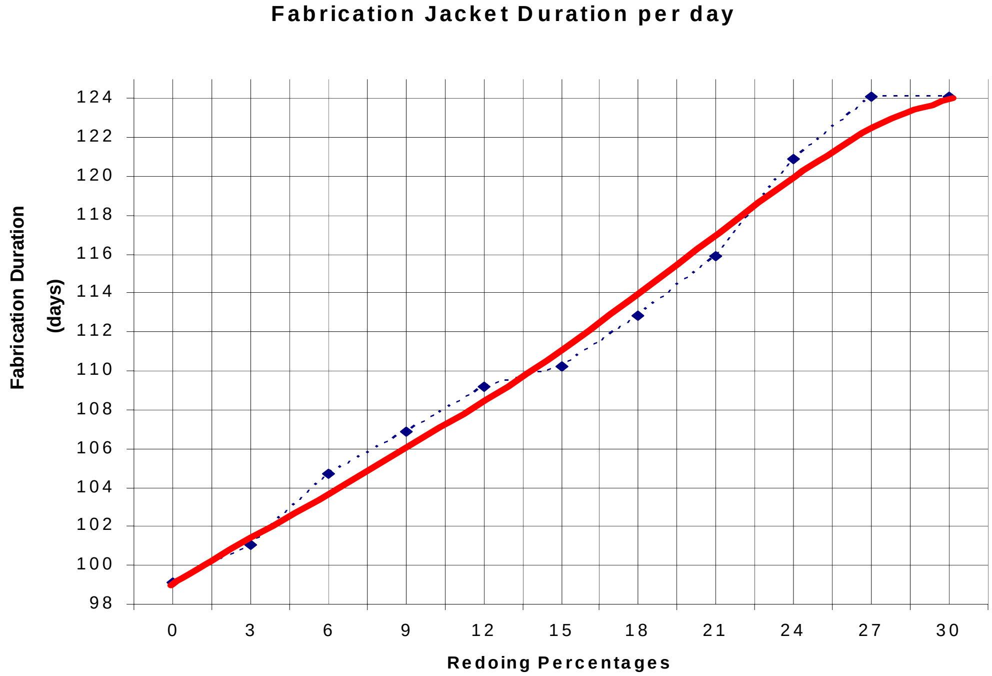



Figure 7: Jacket fabrication duration considering fabricator errors

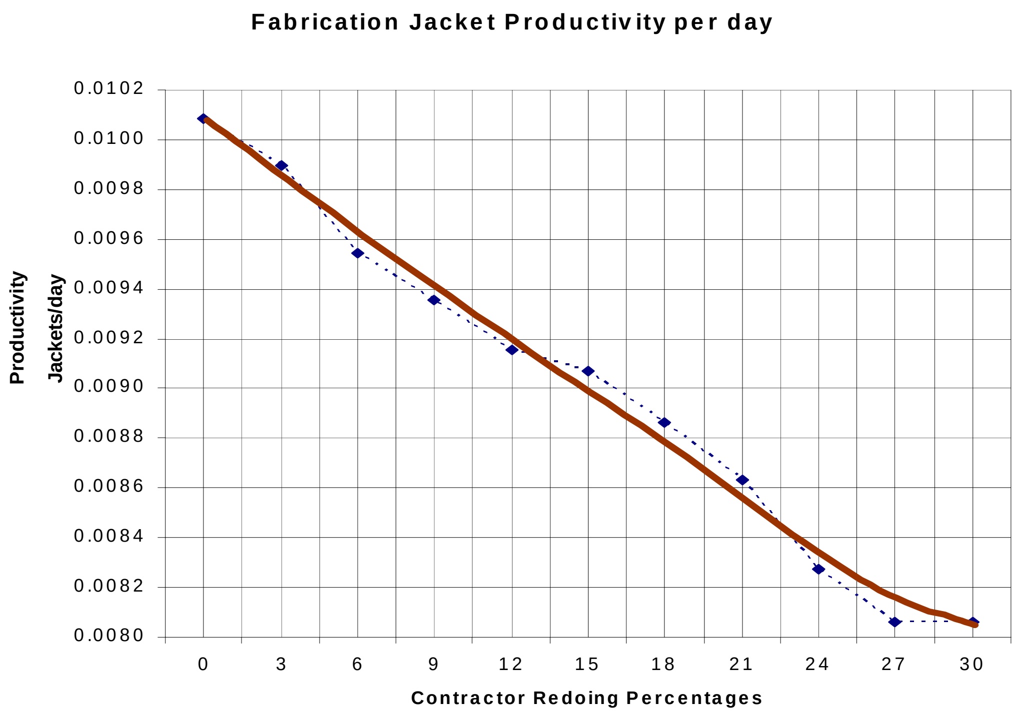



Figure 8: Jacket fabrication productivity considering fabricator errors

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