



A Review of the Current State of Cost Estimating for Maintenance Turnarounds.

by

Gordon R. Lawrence

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<p>AP-Networks LLC <u>Head Office</u> 3 Bethesda Metro Center Suite 925 Bethesda, MD 20814 USA ☎ +1-240-683-1001 📠 +1-240-683-1009</p>	<p>AP-Networks LLC <u>Houston Area Office</u> 18333 Egret Bay Blvd Suite 640 Houston, Texas 77058 USA ☎ +1-281-554-8181 📠 +1-281-554-8585</p>	<p>AP-Networks LLC <u>Netherlands Office</u> Orlyplein 10 Crystal Tower – 24th Floor 1043DP, Amsterdam Netherlands ☎ +31-20-486-1185 📠 +31-20-486-9830</p>	<p>AP Canada ULC <u>Canada Office</u> 444 5th Avenue, SW, Suite 1050 Calgary, AB T2P 2T8 Canada ☎ +1 403 457 2737 📠 +1 403 457 2767</p>
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Abstract

Maintenance Turnarounds are major events for refineries and petrochemical facilities. They typically cost large sums of money to execute. But the cost of executing the turnaround is often dwarfed by the “opportunity cost” of production lost while the facility is shut down. Hence, historically, the development of accurate estimates and strong cost controls has taken a back seat while the focus has been placed on driving the turnaround schedule to minimize the lost production time. However, in recent years, refineries have become more interested in accurate costs as refining margins have narrowed. Similarly, petrochemical plants, where the production opportunity cost driver is less, are also beginning to focus on ideas for improving cost estimating and control.

The technical literature available to the cost estimator wishing to learn more about estimating for capital projects is prodigious. But there is a dearth of similar literature on estimating for turnarounds.

This paper examines the different estimate methodologies used to calculate the base estimate for a turnaround and the effectiveness of those methodologies. It then moves onto a discussion of how allowances and contingency are typically dealt with in turnaround estimates and draws on ideas from the project world to suggest how the calculation of these items might be improved.

The Author



Gordon Lawrence is a Senior Consultant with Asset Performance Networks (www.ap-networks.com), the Maintenance Turnaround and Capital Projects consultancy. He is currently based in The Netherlands.

Gordon has more than 25 years experience in project management practice in the oil & gas, petrochemical, nuclear and pharmaceutical industries. He has worked as a project engineer, project manager and senior project manager in both owner and contractor organizations, including the US contractor, Jacobs Engineering and the Swiss pharmaceutical firm, Novartis. He also previously worked as a consultant in capital project benchmarking at Independent Project analysis. Gordon has been involved with projects and turnarounds across the globe, including China, the Middle East, India, Russia and Eastern Europe.

Gordon is a Chartered Engineer in the UK, a registered professional engineer in the European Union and is a Fellow of the UK Institution of Chemical Engineers. He is also a member of the Association for the Advancement of Cost Engineering International. He holds a Bachelors degree in Chemical Engineering from Heriot-Watt University, Edinburgh, Scotland, a Masters degree in Biochemical Engineering from Birmingham University, England, and an MBA from Strathclyde University Business School in Glasgow, Scotland. He has published numerous articles and conference papers on methods for improving capital project systems and maintenance turnarounds.

Contact: glawrence@ap-networks.com +31 6 81 80 69 23

1 Introduction

1.1 Overview

Maintenance Turnarounds are major events for refineries and petrochemical facilities. They typically cost large sums of money to execute. But the cost of executing the turnaround is often dwarfed by the “opportunity cost” of production lost while the facility is shut down. Hence, historically, the development of accurate estimates and strong cost controls has taken a back seat while the focus has been placed on driving the turnaround schedule to minimize the lost production time. However, in recent years, refineries have become more interested in accurate costs as refining margins have narrowed. Similarly, petrochemical plants, where the production opportunity cost driver is less, are also beginning to focus on ideas for improving cost estimating and control.

The technical literature available to the cost estimator wishing to learn more about estimating for capital projects is prodigious. But there is a dearth of similar literature on estimating for turnarounds.

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1.2 Previous Work

This paper is the third in a series, dealing with aspects of cost estimating for maintenance turnarounds. For a comparison of capital projects and maintenance turnarounds with regard to the stage gated approach to cost estimate development, refer to: Lawrence, “Cost Estimating for Turnarounds in Refineries and other Petrochemical Facilities – Learning from Capital Projects” – Petroleum Technology Quarterly, Q1 2012. For a presentation of benchmarks for cost allowances and contingency in maintenance turnaround cost estimates, refer to: Lawrence, “Analysis Yields Turnaround Benchmarks for Allowance, Contingency” – Oil & Gas Journal, April 2nd, 2012 pp 106-118.

1.3 Database

The analysis in this paper draws on a proprietary database of maintenance turnaround information, maintained and managed by AP-Networks. AP-Networks maintains turnaround databases for both upstream and downstream facilities. This paper utilizes the downstream database. The Downstream database contains several hundred turnaround records, from a range of major oil and petrochemical firms for refineries and major chemical facilities around the globe. It includes information on scope, contract strategy, costs, hours and schedules.

1.4 What is a Maintenance Turnaround?

A maintenance turnaround (in the context of the process industries) is defined by the American Petroleum Institute as “a planned, periodic shut down (total or partial) of a process unit or plant to perform maintenance, overhaul and repair operations and to inspect, test and replace process materials and equipment”¹. Refineries and other petrochemical facilities that run on a continuous rather than a batch production cycle must, every few years, shutdown operations in order to provide access to the production units, so that essential maintenance, modification and inspection work can be carried out that could not be done whilst the units are in operation.

Turnarounds are events that are (ideally!) planned well in advance and typically take place on a 4 to 6 year cycle. The length of the execution phase of a turnaround (i.e. the period when the facility is shutdown and hydrocarbon free) is typically around 3-5 weeks.

The scope of a maintenance turnaround usually includes:

- Inspection of equipment to comply with company regulations or government mandatory rules e.g. pressure vessel inspection).
- Inspection of pipework for corrosion and erosion damage, both internal (e.g. process weak points) and external (e.g. corrosion under insulation, or CUI).
- Cleaning, repair and maintenance of equipment, pipework and instrumentation (e.g. pulling & cleaning heat exchanger tube bundles, leak detection & repair [LDAR], or checking of pressure relief valves).
- Minor upgrades and modifications to the facilities (items controlled under the “management of change” [MoC] procedures).

In addition, major capital project teams will frequently use the occasion of a turnaround to carry out tie-in work for their project.

2 Turnaround Cost Estimate Accuracy

A cost estimate needs to be accurate in order to (a) provide management with the information needed to decide how (or whether) to proceed; (b) to allow cash-flow planning; and (c) to aid in firm control of expenditure.

2.1 Intended Level of Accuracy

As shown in Figure 1, in a survey of conference participants at the Turnaround Industry Networking Conference (TINC) – Europe, held in March 2011 in Amsterdam, The Netherlandsⁱⁱ, 83% of respondents said that their turnaround control budget was intended to be a $\pm 10\%$ estimateⁱⁱⁱ. The remaining 17% said that their estimate was supposed to include sufficient contingency/reserve that it was a “not to exceed” number. None said that their budget was intended to be a $\pm 30\%$ or a $\pm 50\%$ estimate.

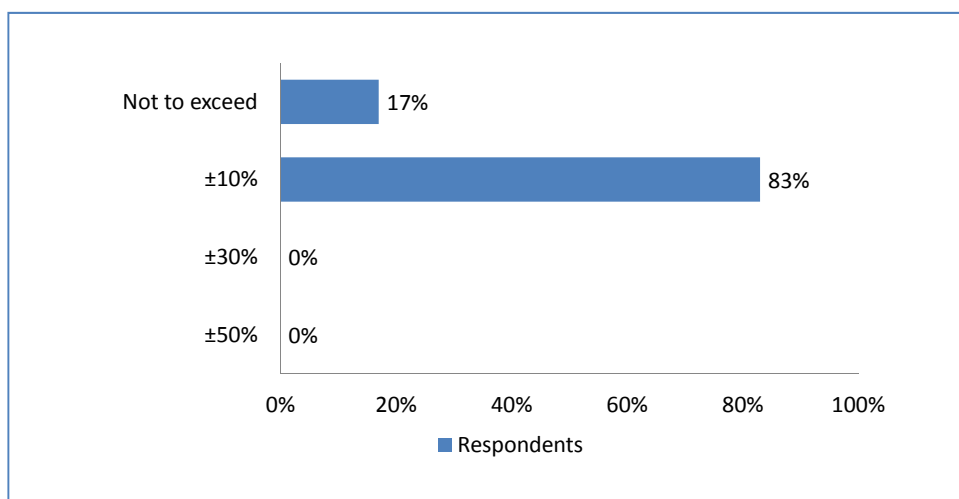


Figure 1

2.2 Actual Level of Accuracy

We took the maintenance portion (i.e. excluding monies for major project tie-ins) of the turnaround control budget for 133 refinery turnarounds and compared that to the actual cost at the end of the turnaround.

The first column in Figure 2 shows the idealized P10 to P90 range (black vertical line) and the mean (red horizontal line) that one would expect to see plotted for a set of turnarounds that professed to have a control estimate with an accuracy of $\pm 10\%$.

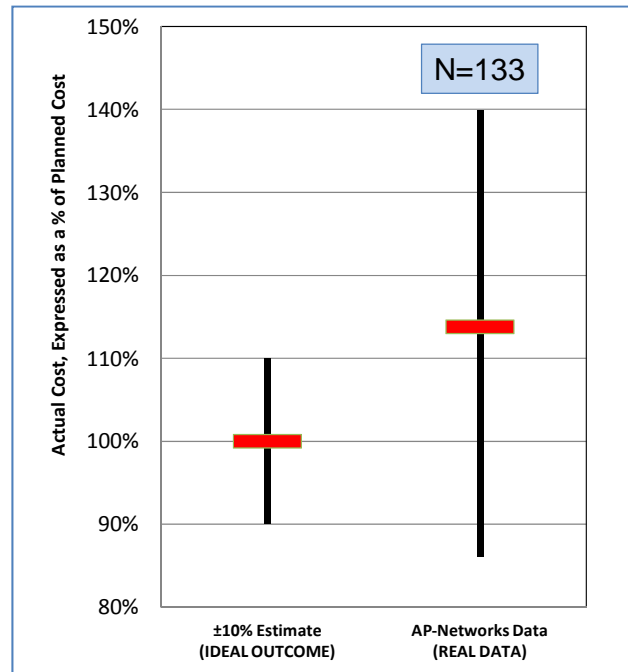


Figure 2

The second column shows the actual result for our dataset of turnarounds. As can be seen, the turnarounds in that set overran their estimates by an average of 14% and had a range of accuracy of closer to $\pm 25\%$ than the expected $\pm 10\%$.

3 Estimate Methodologies Used

Let us now look at the different methodologies used by maintenance turnaround teams to develop their estimates, to see if that makes a difference to the accuracy achieved.

3.1 Categories of Methodologies Used

The first problem that we encountered in examining the methods used by teams to develop their cost estimates is that the concept of documenting the “Basis of Estimate” is completely foreign to turnaround teams. Nevertheless, we have been able to allocate cost estimates into one of 5 broad categories. These are:

3.1.1 A: Industry Benchmark

The cost estimate is simply the benchmark of what the historical data says the turnaround “should” cost. This benchmark is generally either a “business” benchmark or a “scope” benchmark.

“Business” benchmarks are provided by firms such as Solomon Associates^{iv} or the Juran Institute^v. These benchmarks take no account whatsoever of the scope of what is to be done. They merely look at what, from a business point of view, the refinery can spend and still remain competitive in its operations.

“Scope” benchmarks, provided by AP- Networks^{vi} look at the scope of work to be carried out. They provide a benchmark of what other firms in the industry typically spend to carry out that amount of scope.

3.1.2 B: Extrapolation of Historical Cost Information

In this method, the cost estimate is simply the cost of the previous turnaround, escalated to present day conditions and with minor adjustments made for whatever (if anything) is known about differences in scope between the present and past turnarounds.

3.1.3 C: Bottom-Up, Detailed Estimate

This method is the most detailed. In this method, the work-packs^{vii} for all work, in all disciplines are complete. Prices for both material and labor have been cross-checked and confirmed by contractor or vendor quotes.

3.1.4 D: Mix of Benchmark & Historical

This option covers those turnaround teams that have taken a benchmark and carried out some sort of simple “sanity-check” adjustment, using historical data.

3.1.5 E: Mix of Historical & Bottom Up

This option covers those turnaround teams that have developed some element of the scope to the detailed, bottom-up level, but have not taken all elements of the scope to that level. Most typically this is one of two versions:

- Mechanical work-packs completed and priced internally. Everything else factored off mechanical using historical ratios.
- Mechanical work-packs completed and prices cross-checked/confirmed by quotes. Everything else factored off mechanical using historical ratios.

3.2 Level of Use of Each Methodology

As can be seen in Figure 3, unsurprisingly, option “A”, the industry benchmark and option “D” the adjusted benchmark, are the least used by turnaround teams for their control estimates. Most teams extrapolate from past data, do a detailed estimate, or do some combination of the two.

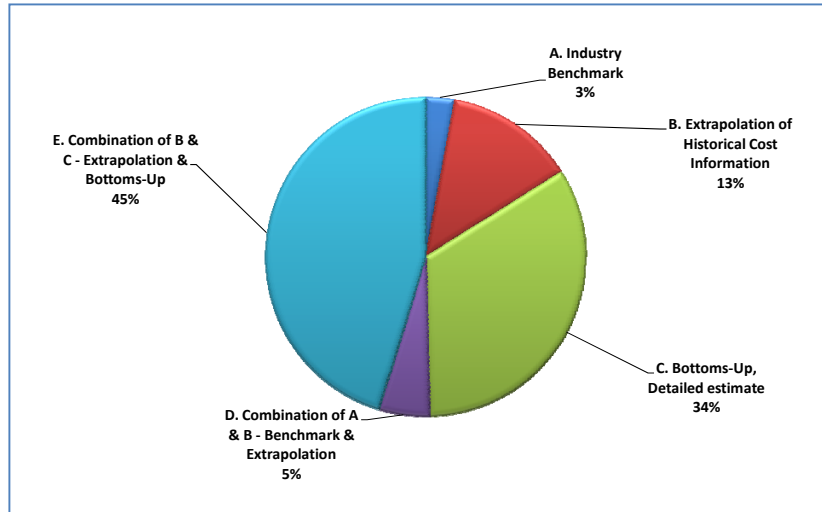


Figure 3

3.3 Correlation of Methodology with Outcomes

We then took our sample of turnaround outcomes from Figure 2 and split the set by methodology used. In Figure 4 we can see that when the data from Figure 2 is split by estimating methodology, it becomes clear that; (1) extrapolation is wildly inaccurate; (2) the bottom up estimate is (unsurprisingly) the most accurate; and (3) a combination of the two is somewhere in between. The bottom up estimate method yields the best results.

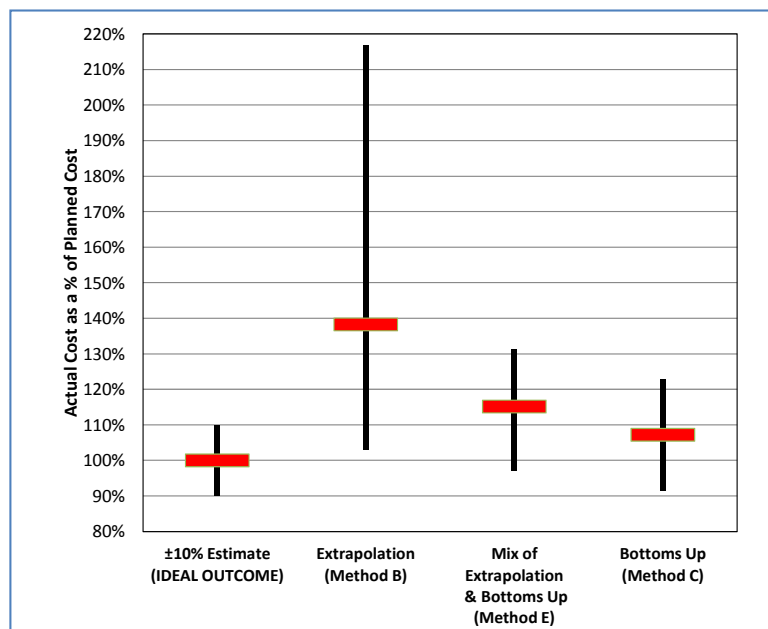


Figure 4

The combination of the two is closer to the bottoms up method than the extrapolation method in terms of accuracy. This is probably because in most cases the teams do take the time to develop the mechanical scope to a detailed level. Since the mechanical scope is

generally the overwhelmingly largest discipline (typical rule of thumb, about 33% of the total direct field labor hours), this is perhaps also unsurprising.

4 Cost Estimate Progression

4.1 The Point at Which the Budget is Set

In capital projects, a stage gated process allows project teams to gradually use more sophisticated estimating methods (capacity factors, equipment cost factors, detailed material take-off [mto], etc.) to gradually improve the accuracy of the cost estimate. Maintenance turnaround teams have a similar system of gradually more sophisticated estimate methods available to them, as discussed earlier in this paper. (benchmarks, historical data, detailed mto). The problem is that, unlike in capital projects, the concept of gradually improved estimates, as the work develops is not as ingrained in the turnaround world.

In the project world, the final investment decision is made, based on the final estimate and hence the requirement is to calculate how much money is needed to complete the defined scope. But in the turnaround arena, the budget is often set “in stone” at the early estimate stage and hence the requirement becomes a need to decide how much scope can be completed for the defined amount of money^{viii}.

Naturally, the maintenance and operations teams want the greatest amount of scope possible to be completed in the turnaround. There is also the temptation of knowing that once the execution phase of a turnaround has begun, it’s hard to drop scope, even if costs are overrunning. Hence the stage is set for over-optimism about the amount of scope that can be done to clash with the hard barrier of what the finance department wishes to spend.

4.2 Over-Optimism in Early Estimates

Capital project teams often expect that their estimates will progress in accuracy as shown in Figure 5. However, numerous studies (including Hollmann [2012]^x or Merrow, Phillips & Myers [1981]^x, or Flyvbjerg, Bruzelius & Rothengatter^{xi} to name but three) have shown that teams and/or their management tend to be over-optimistic during estimate preparation. Hence, the reality is more like Figure 6.

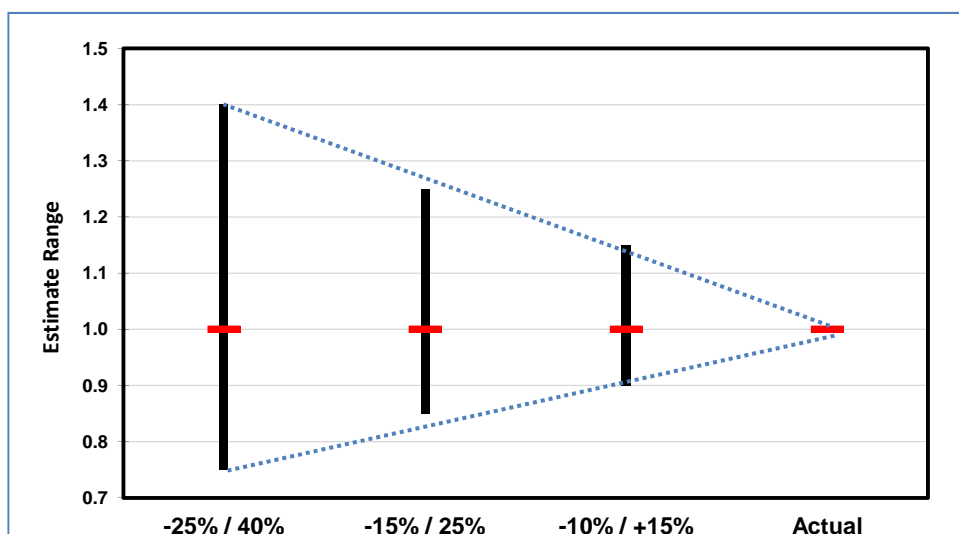


Figure 5

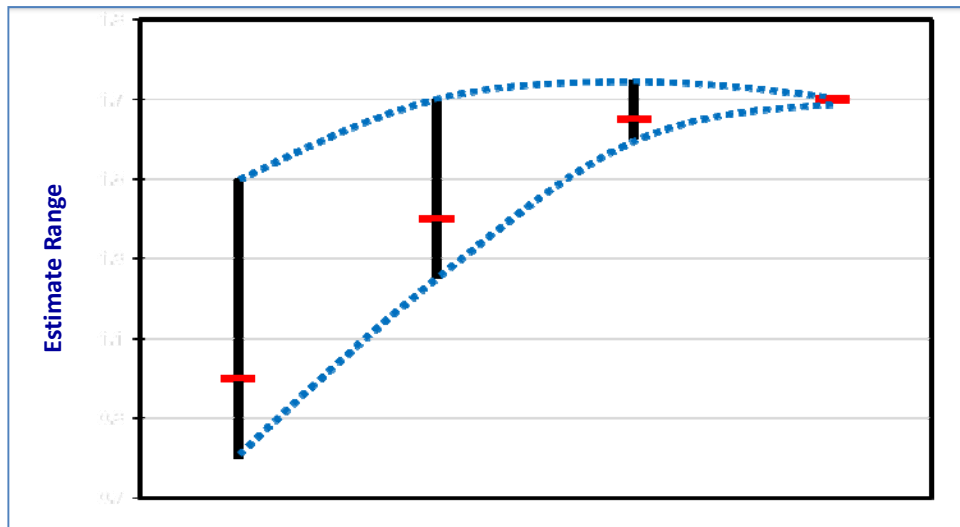


Figure 6

There is no great reason to suppose that maintenance teams are any more realistic in their estimating than project teams. Hence the results shown in Figure 4 should come as no great surprise. Estimates developed using simpler methods tend not only to have wider accuracy ranges, but also tend to under-estimate the mean value. A lot of this under-estimation can be logically traced back to an over-optimistic view of the amount of allowance for unknowns that should be included in an estimate.

5 Allowances for Unknowns

Just as with a cost estimate for a capital project, the turnaround cost estimator needs to make allowance for various “unknown” quantities in the estimate.

5.1 Different Types of Unknowns

In a capital project those unknowns are covered by development allowances and contingency. In a turnaround cost estimate the unknowns are typically discussed by turnaround teams in three categories, discussed below:

5.1.1 Emerging Work

When deciding on the scope of maintenance work for a turnaround, ideally a turnaround team will hold a scope “gathering” phase (work that people would like to be included in the turnaround), followed by a “challenge” phase (questioning whether the work really needs to be included or could instead be postponed to the next turnaround or done online, during normal operations). The team will then impose a scope “freeze” date, after which any new scope has to go through a “change control” approval process before it will be added. This is analogous to the change control process imposed after design freeze on a capital project.

The emerging work category of unknowns discusses scope items that appear after scope freeze (but before the start of the turnaround execution) and successfully pass through the change control process to be included in the turnaround scope. There are two main groups in this category:

5.1.1.1 Emerging - “Forgotten” Work

This group covers items that should have gone into the scope during the scope gathering phase, before the scope freeze, but which were overlooked or forgotten.

5.1.1.2 Emerging – Breakdown Work

This group covers items that break down between scope freeze and the start of execution.

5.1.2 **Discovery Work**

This category is for work that is “discovered” during execution, once equipment is opened up. (Example; upon opening a distillation column for inspection the team discovers several damaged trays that need to be repaired).

5.1.3 **True Contingency**

This category is a catch-all allowance for inefficiencies and inaccuracies (i.e. stuff that takes longer and/or costs more than expected).

5.2 **Making Allowance for Unknowns in the Estimate**

As shown in Figure 7, among turnarounds in our database, only 21% of turnaround teams bother to show allowances as a specific, definable line item in the cost estimate.

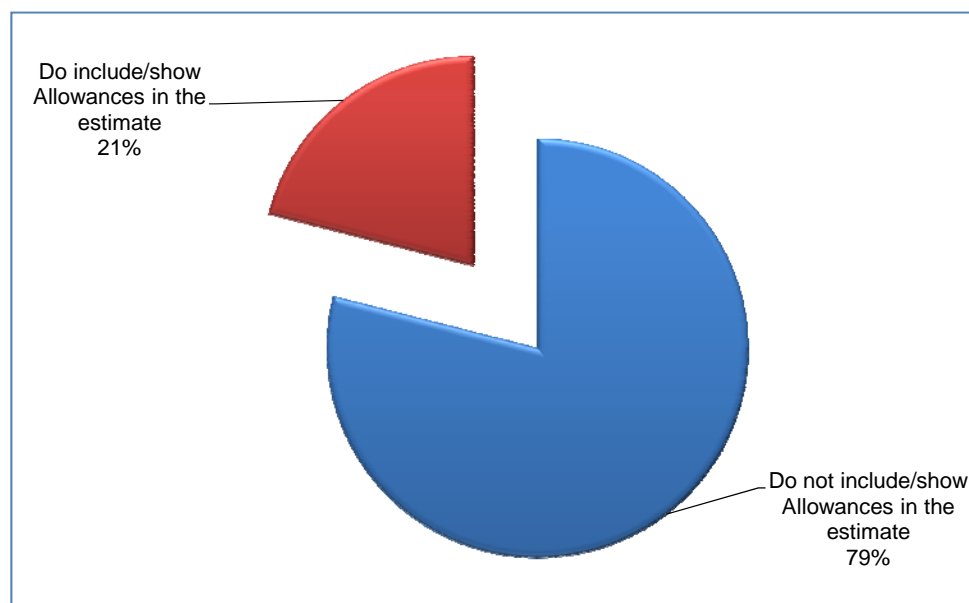


Figure 7

Whether those who do not show allowances are merely hiding the allowances in the line items or are simply not making any allowance, is hard to determine, due to the earlier mentioned lack of clear explanation or basis of estimate documentation available from turnaround estimators.

5.3 Giving a Breakdown of Allowance Allocations in the Estimate

As shown in Figure 8, of those who do show allowances as a separate item in the estimate, few actually split them up into Emerging, Discovery and Contingency.

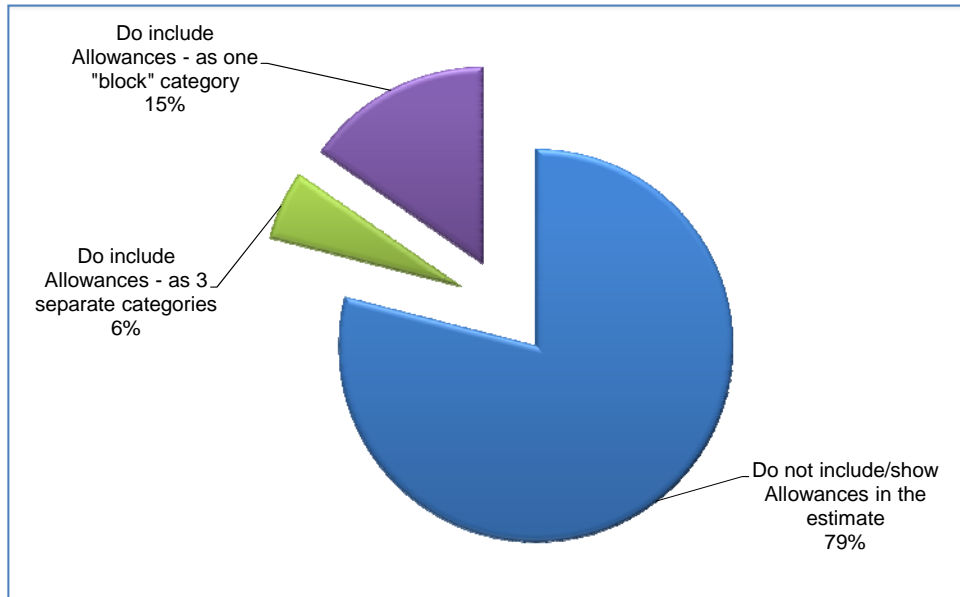


Figure 8

Let us now take those teams who use a detailed, bottom-up method of estimating, discussed in Figure 4 and look at those from that group who do take the trouble to differentiate the different types of allowance into the three main groups. These teams already had the most accurate estimates. As indicated in Figure 9, those teams that used the bottom up methodology and also differentiated the three types of allowance tended to be in the lower (more accurate) half of the bottom-up set and hence achieved even more accurate results.

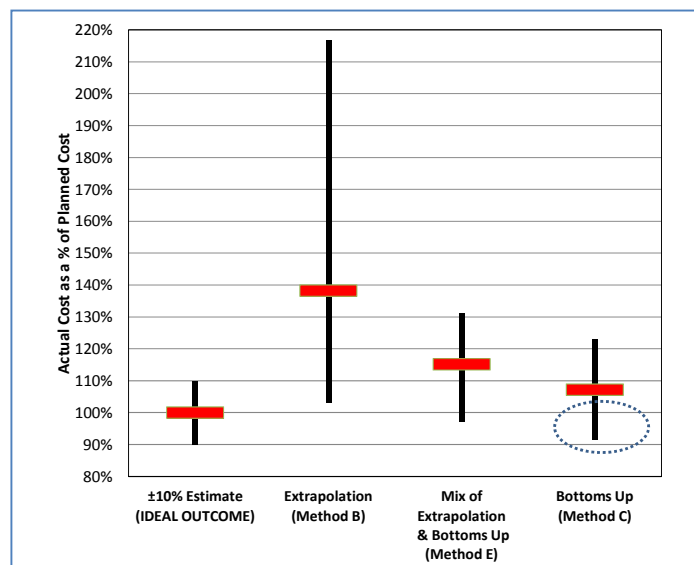


Figure 9

5.4 How Much Allowance to Include

As shown in Figure 10, turnaround teams tend to include an average of 11% (expressed as a percentage of maintenance budget excluding allowance), with very little variation around that average. However, as already discussed, this is clearly insufficient.

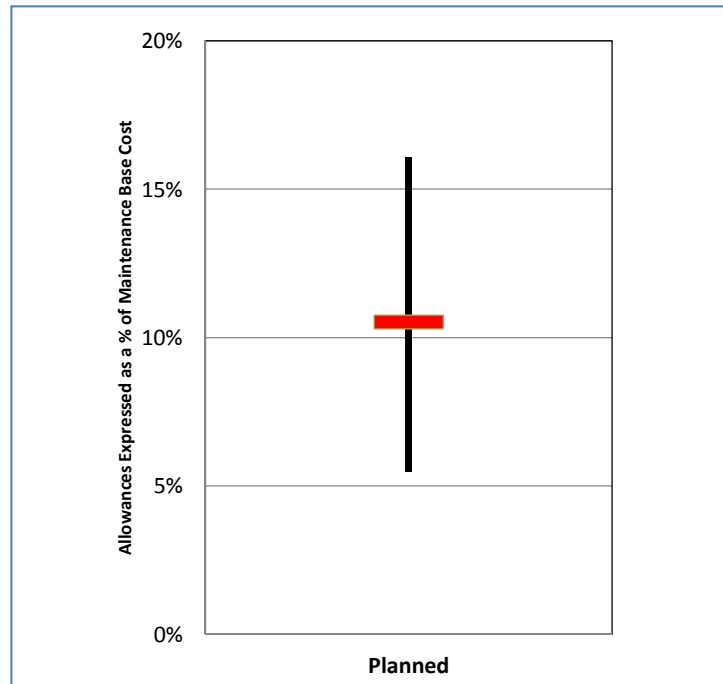


Figure 10

That average amount for allowances tends to break down into the three allowance categories roughly in the proportions shown in Figure 11.

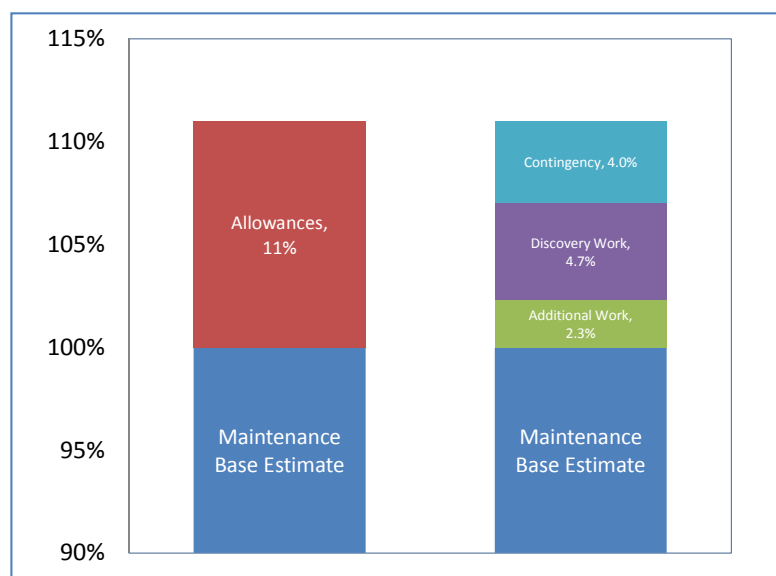


Figure 11

Unfortunately, no team has yet been able to provide us with a comparison of actual expenditure of allowances, broken down by those three categories.

5.5 Calculation Methods for Allowances

Just as in the project world, there are effectively four different ways of calculating the allowances to put into the estimate. These are:

5.5.1 Pre-Determined Percentage

In this method, company procedures decree that a flat percentage is to be used on all estimates.

5.5.2 Expert Judgment

This method relies on the opinion of team members to allocate an amount.

5.5.3 Monte Carlo

In this method, teams use an outcome simulation system such as AP-Networks CERA methodology^{xii} to develop a probability curve of likely required allowance.

5.5.4 Statistical Regression Model

This method is not, to our knowledge in use by any teams at this time. At AP-Networks we are in the throes of developing a model to calculate allowance amounts.

5.6 Breakdown of Calculation Methods by Level of Use

In general, the most popular method used by turnaround teams is expert judgment, based on the past experience of the team members and the historical information available to them. However, as we have seen earlier, this judgment is clearly under-estimating the amount required.

5.7 Separating Allowances from “True” Contingency

In order to be able to estimate likely allowance requirements with more accuracy, it would aid turnaround teams if they were able to focus their expert judgment more specifically on known elements of the turnaround scope.

In the capital project arena, a clear distinction is made between development “allowances”, which can be assigned to specific line items in the estimate; and true “contingency”, which is “An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs.”^{xiii}; or in other words, money that will be needed somewhere but which cannot be assigned to any particular line item in the scope.

If we follow the same logic for turnarounds, then we can see that Emerging Work and Discovery Work could, arguably, be treated as allowances and assigned to specific line items in the estimate. This would then only leave the “true” contingency requiring expert judgment^{xiv}. Consider:

5.7.1 Emerging - Forgotten Work

If the initial scope gather and challenge is done well, then nothing should have been overlooked or forgotten and this allowance falls to zero.

5.7.2 Emerging –Breakdown Work

This could be estimated for each line item, based on plant maintenance history. For example: “We normally have 3 valves per month that fail. Between now and the shutdown there are 9 month. Therefore we should make allowance in Emerging Work for 27 valves to fail.”

5.7.3 Discovery Work

This too, could be estimated for each line item, based on plant operations experience. For example: “Distillation column XYZ is only working at 70% efficiency. The most likely reason is that trays A, B and C are damaged. Therefore, we should allow for replacement of those trays in the Discovery Work allowance.”

5.7.4 (True) Contingency

If emerging and Discovery Work can be estimated in this way, that leaves only the allowance for inefficiency to be the true contingency that requires expert judgment.

6 Conclusions

Currently, on average, across the refining industry, cost estimates for turnarounds are not accurate. However, when turnaround teams are willing and able to take the time to develop the estimate to a detailed mto level, with good budget quotes, the effort pays off, with more accurate estimates.

Turnaround teams tend to be over-optimistic about the amount of allowance and contingency that their budget should contain. Dealing with emerging work and discovery work as allowances for specific, expected events should help to improve the accuracy of allowance and contingency requirements.

ENDNOTES

ⁱ <http://www.api.org/aboutoilgas/sectors/refining/refinery-turnaround.cfm>

ⁱⁱ <http://ap-networks.com/events/tinc-europe-2013.html>

ⁱⁱⁱ We are very aware of the fact that in recent years the preference within project cost estimating circles is not to talk of a typical $\pm 10\%$ or $\pm 30\%$ estimate, but rather to talk of “classes” of estimates. This is because of the need to recognize that for the same level of scope definition, two projects could have different levels of estimate accuracy because of the inherent risks in their characteristics. For example a new technology project probably carries more risk than a similar size project expanding an existing plant. However, the Turnaround world has not yet reached that level of sophistication. Hence, for the survey we used terms that are readily recognized by turnaround teams, such as $\pm 10\%$ estimate.

^{iv} <http://solomononline.com/>

^v <http://www.juran.com/>

^{vi} <http://ap-networks.com/services/turnaround-benchmarking.html>

^{vii} A well prepared work-pack will include a complete description of the work to be carried out, with drawings, photographs and detailed material take-off.

^{viii} See Lawrence, “Cost Estimating for Turnarounds in Refineries and other Petrochemical Facilities – Learning from Capital Projects” – Petroleum Technology Quarterly, Q1 2012 for further discussion of this point

^{ix} Hollmann, J. K., Estimate Accuracy: Dealing with Reality, Cost Engineering, pp17-27, Nov/Dec 2012.

^x Mellow, E.W., Phillips, K. E., Myers, C. W.: Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants, R-2569-DOE, The RAND Corporation, 1981

^{xi} Flyvbjerg, B., Bruzelius, N., Rothengatter, W., Megaprojects and Risk: An Anatomy of Ambition, Cambridge University Press, 2003.

^{xii} <http://ap-networks.com/services/cera.html>

^{xiii} Definition from the Association for the Advancement of Cost Engineering – International (ACE-I)

^{xiv} Indeed, an argument could even be made that Discovery work should not be in the estimate at all, but instead should be held separately as a “risk” fund, to be drawn upon only if and when the specific “discovery” item occurred.