



An Analysis of Influences on Estimating Practice in Software Projects

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An excerpt of a research dissertation submitted to

UCD Smurfit Graduate Business School
University College Dublin, Ireland

For the degree of

Master of Science (MSc)

Project Management

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Abstract

The impact of inaccurate estimates through *under-estimation* can lead to significant financial loss for organisations (both service providers and clients) and a drain on strategic resources. Conversely, effort *over-estimation* can erode competitiveness due to lost business or inefficient usage of resources in delivering a project. Unfortunately, research illustrates that estimates are more often inaccurate, than they are accurate, and that the software industry in particular suffers from a chronic estimation track record resulting in frequent and unacceptably high project overruns.

Estimating terminology, processes and techniques are not well understood and empirical results show that estimate inaccuracy is such that most projects (60-80%) encounter effort and/or schedule overruns with the average effort overrun for projects in the range of 30-40% with estimates that are strongly biased towards over-optimism.

This thesis synthesises the current research and respected wisdom on estimation and presents primary research into the estimation practices in use and the cognitive biases and other exogenous influences that can affect an effort estimate. Based on a cross-industry, international survey of 151 experienced project management and software engineering professionals, it was found that (a) most estimators outside of service provider organisations in industry are not trained; (b) most organisations do not have a mature or repeatable estimating process; (c) there are multiple estimating approaches in use and that there is no single best estimating approach; (d) there is a significant lack of rigour in the application of estimation best practices; and (d) there are significant influences that affect project estimates.

In conclusion, ten recommendations are proposed for Irish industry to address these issues via (1) adoption of a project estimating standard and a maturity model; (2) formal training and designation of lead estimators; (3) mandating the use of an estimating checklist; (4) creation of a central repository for

historical data and measuring estimation accuracy; (5) adoption of Jørgensen's 12 best practice guidelines for expert estimation; (6) fostering a culture of accountability for estimates; (7) avoiding unjustified low cost bids; (8) adoption of non fixed price \ fixed scope contracts for agile developments in the Public Sector; (9) undertaking an Irish industry benchmark survey of ICT project estimation performance; (10) Establishing an ICT Business Value Research Observatory.

Keywords: *Accuracy, Adverse Selection, Benchmarking, Best Practice Estimation, Competitive Bids, Cognitive Biases, Estimation, Estimation Error, Expert Judgement, Forecasting, Formal Models, Heuristics, 'Must-win' Bids, Parametric Models, 'Price-to-Win' Strategy, Probability, Psychology of Estimating, Software Engineering, Variance.*

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1 Representation and Sampling

To ensure the population only included experienced respondents, the survey instrument was designed to only allow responses from those who could answer YES to the following two questions online:

- Q1. Are you experienced in estimating software projects?
- Q2. Have you estimated projects with effort greater than 60 man days (480hrs) or a value greater than EUR, USD, STG 60,000?

Those who answered YES to both of the above questions are considered valid respondents and would then be presented with the full survey to complete online.

The overall sample results are as follows:

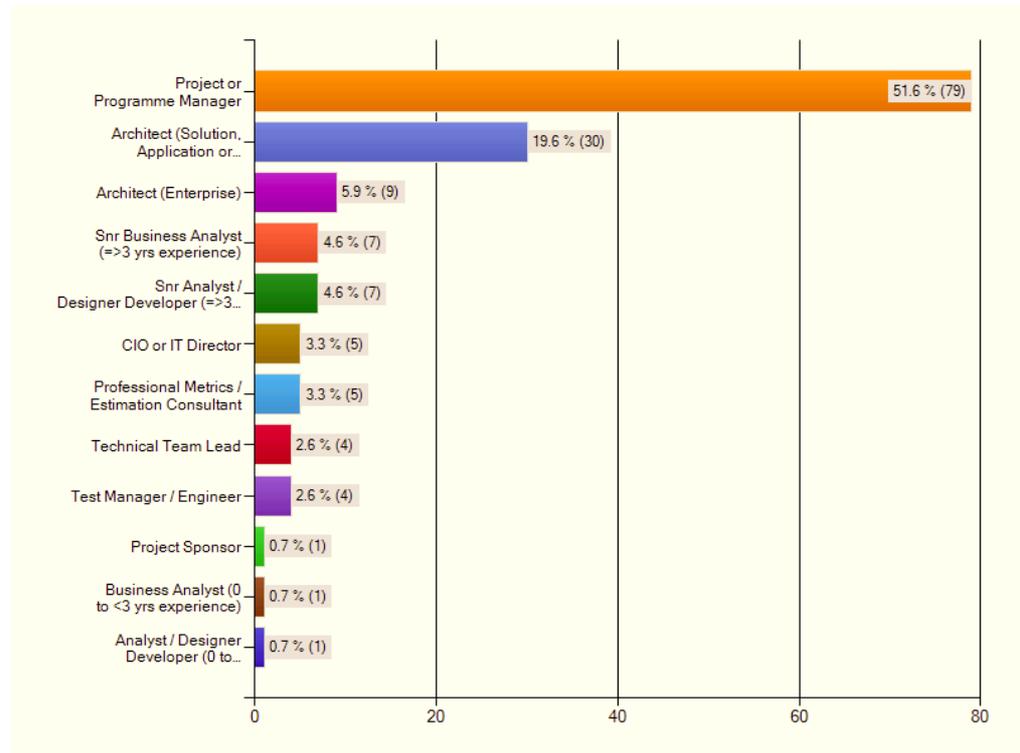
- 266 responses were attempted in total by the population;
- 86 units were abandoned giving an abandonment rate of 33% of the valid surveys that commenced;
- 27 responses were invalid, i.e. they answered NO to one or both of the validation questions;
- In summary, the total number of responses completed was 153. This gave a response rate of 57.5% from the valid population who responded ($\sum 153 / (266-27)$); and
- The response rate is in the higher quartile in comparison to other high response modes, such as mail and significantly above the mean response rate found by other researchers for Internet surveys (Shih and Fan 2009, Fan and Yan 2010).

The sample (n=153) is considered reasonable in its size and representation to explore the research questions posed by this thesis and to make relevant inferences.

The generalisation of these results must be done with care as with all self-reported surveys they are subject to a number of biases, most notably the social desirability bias.

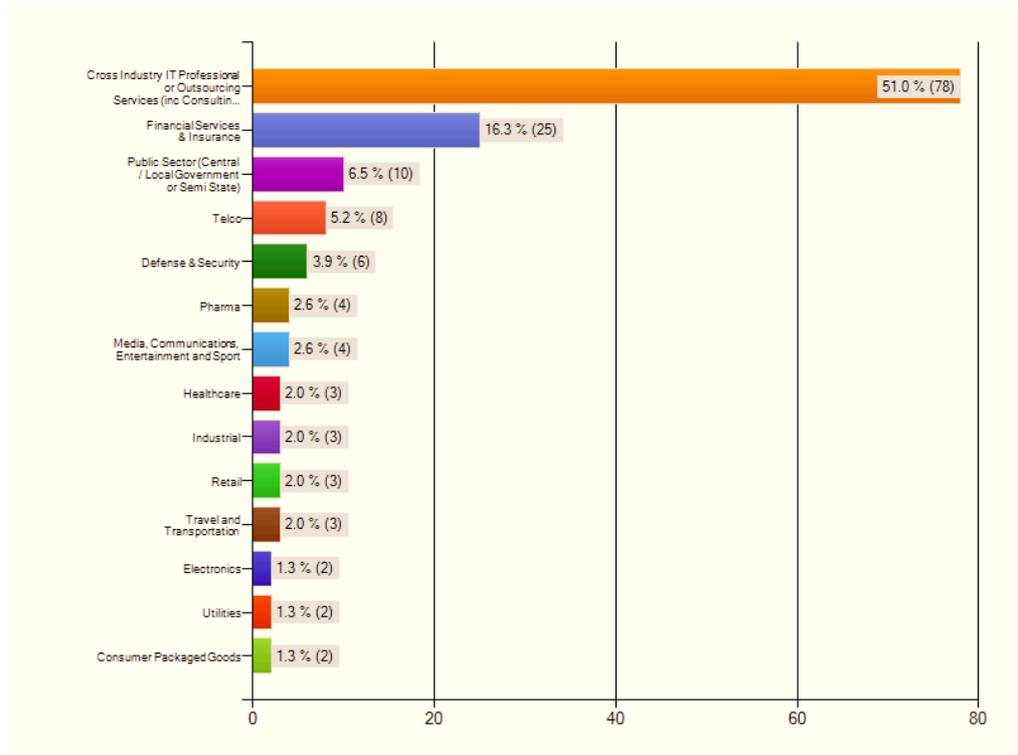
1.1.1.1 Sample Characteristics

Figure 1-i - Respondent Role within their Organisation



The Project or Programme Manager role within the population is the most dominant role for respondents in terms of estimating of software development projects (51.6%, n=79/153).

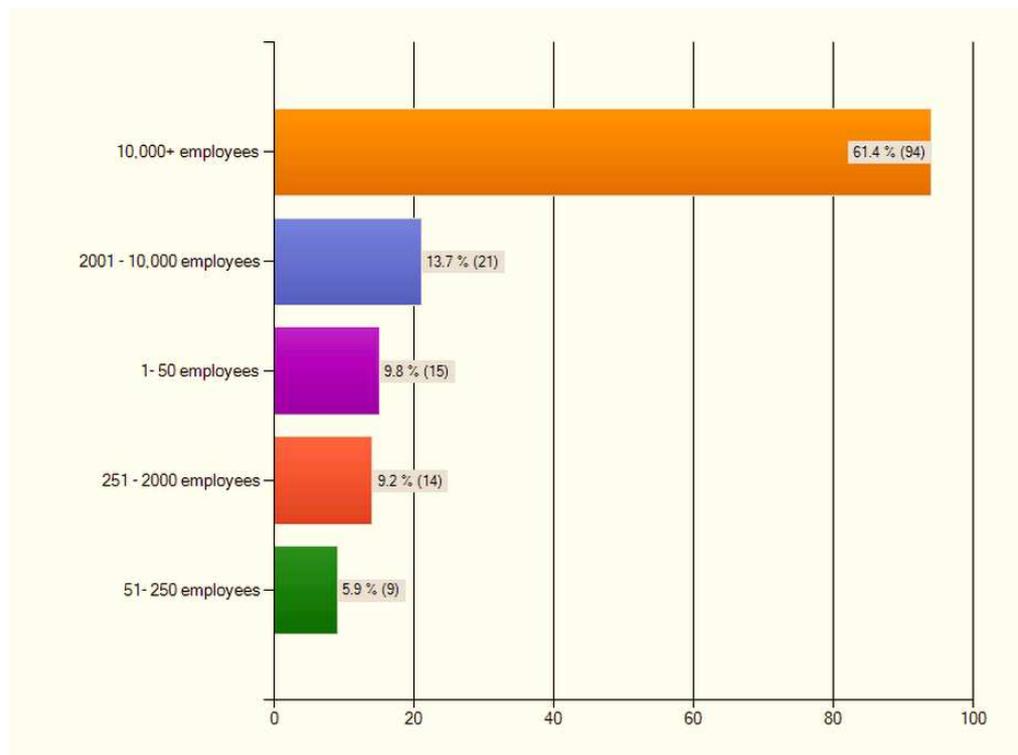
Figure 1-ii - Respondent Organisation by Industry



There is a balanced representation from the both the IT services industry and collectively the other non-IT services industries combined.

- The majority of survey respondents are from the IT Services industry (51%, n=78/153);
- The next largest industries represented are Financial Services (16.3%, n=25/153) and the Public Sector (Central and Local Government with 6.5%, n=10/153);
- In terms of a single industry the sample is over-skewed towards the IT Services industry above all other industries; and
- The remainder of the sample are cross industry and not within the IT services industry (49%, n=75/153).

Figure 1-iii - Respondent's Organisational Size (Worldwide)



There is a dominance within the survey of large organisations responding to the survey (61.4%, n=94/153).

- Small organisations with employees of 51 – 250 employees are under-represented in the sample (5.9%, n=9/153).

Figure 1-iv - Role in Estimating for Internal or Commercial Projects

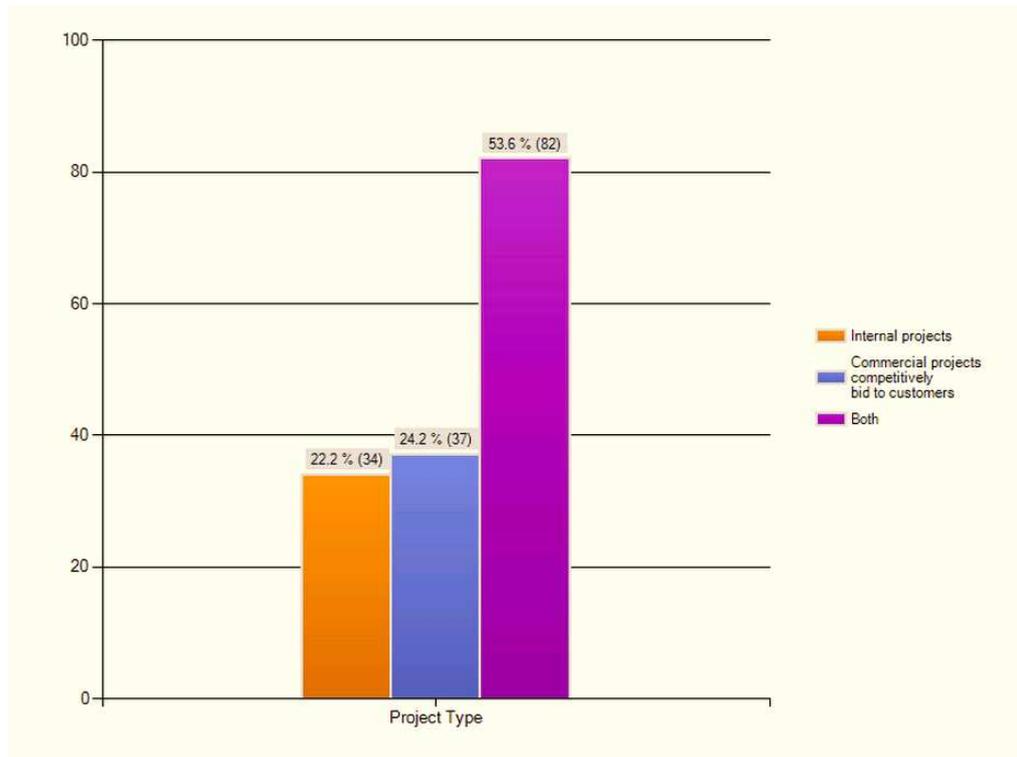
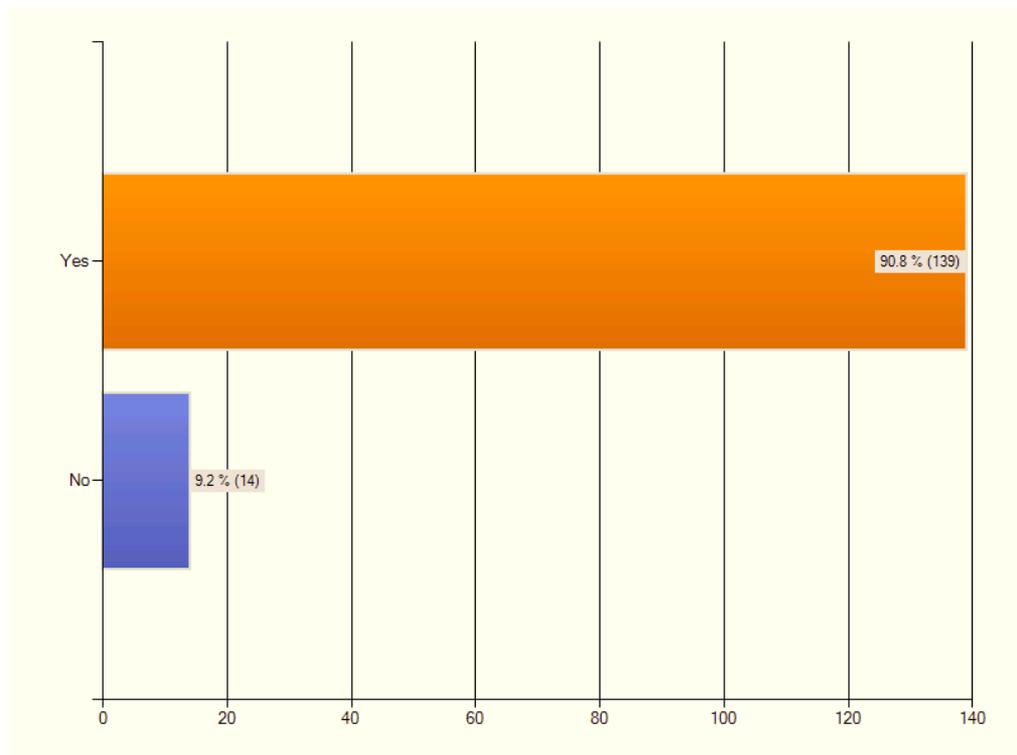


Figure 1-v - Percentage of Estimators Involved in Project Delivery



The majority of respondents are involved in estimating both in-house and commercial projects (53.6%, n=82/153) and all also involved in the delivery of the projects for which they estimate, (90.8%, n=139/153).

2 Research Results

The results of the research survey are included in this chapter. These results are organised under each of the research questions defined in **Error! Reference source not found.**

2.1 Research Question 1 Results

RQ1: Are Estimators Formally Trained?

Figure 2-i - Percentage of Respondents Formally Trained in Estimation

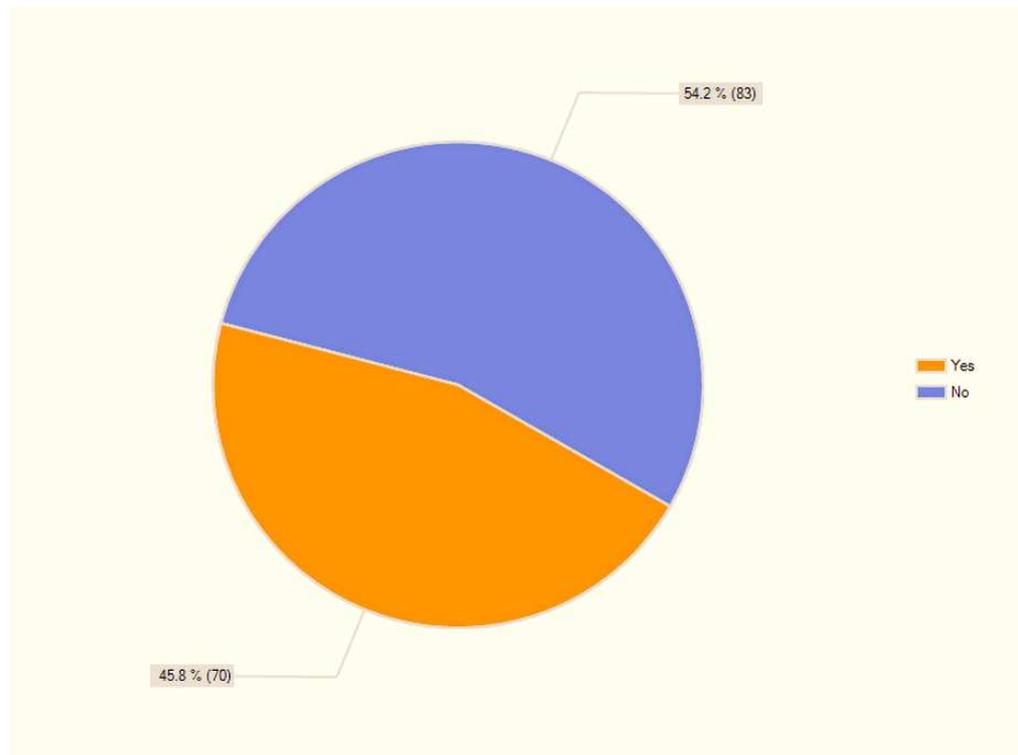


Figure 2-ii - Percentage of Respondents Formally Trained by Industry

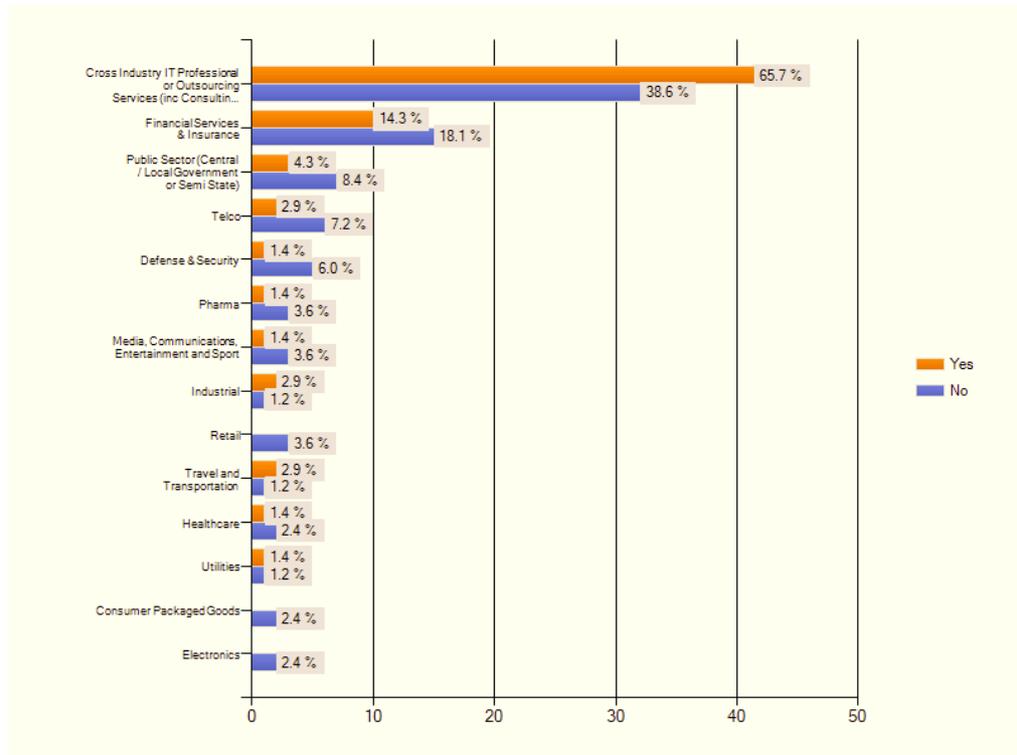


Figure 2-iii - Respondent's Experience in Estimating Effort

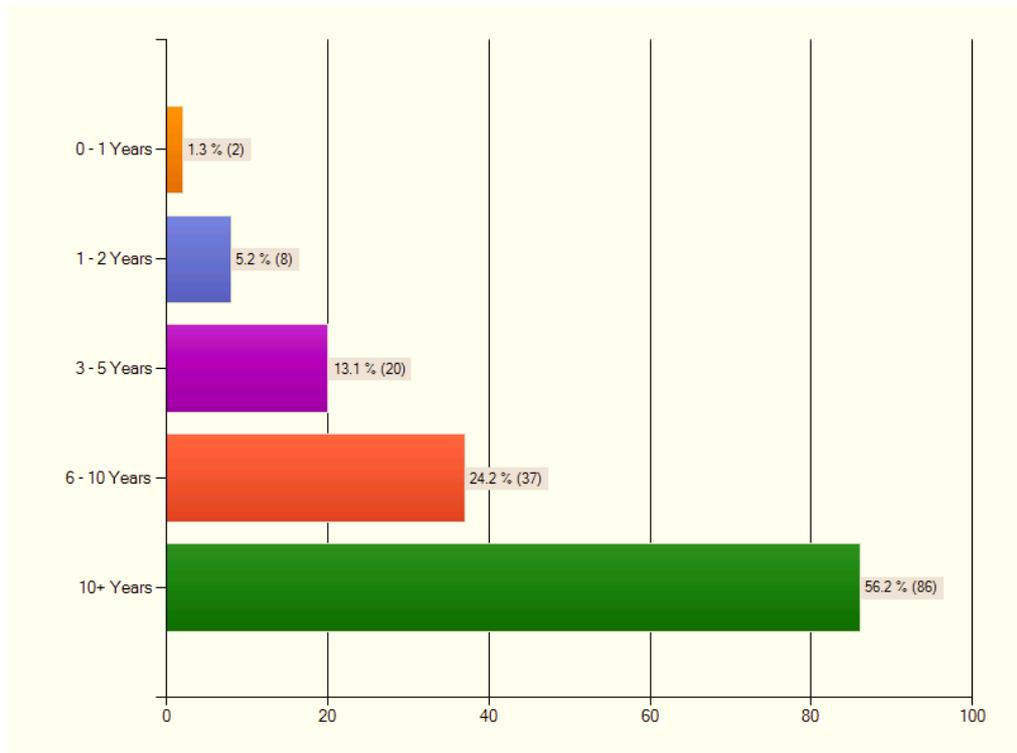
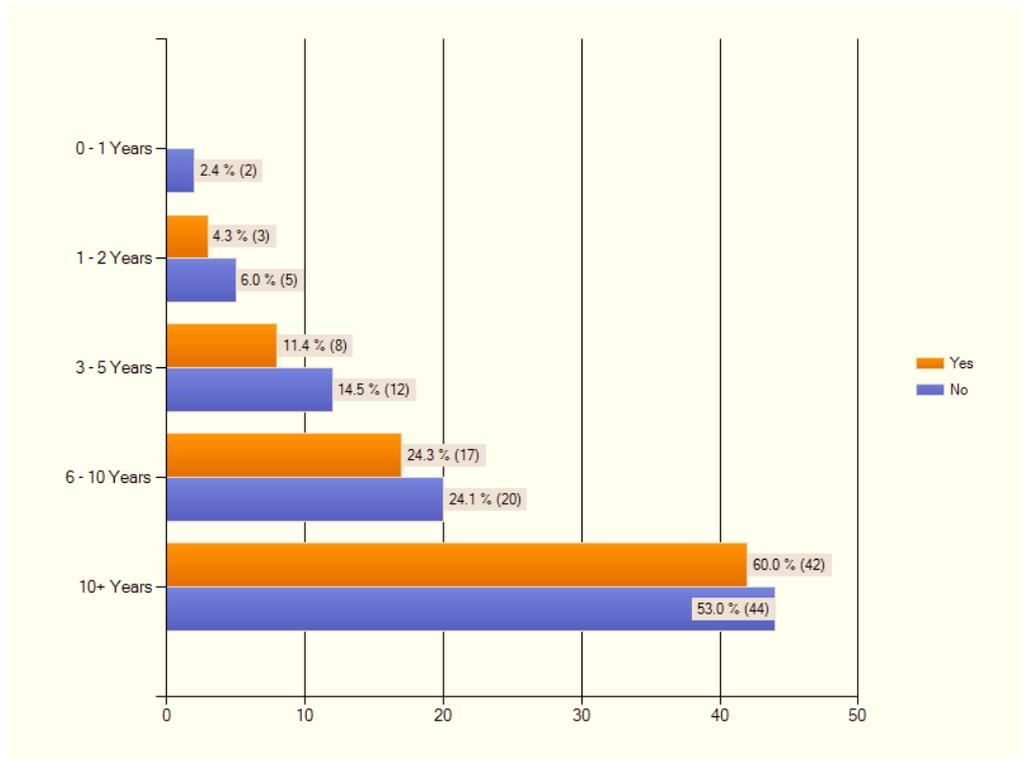


Figure 2-iv - Years of Estimation Experience & Also Formally Trained



The key findings for this research question are:

- The majority of those who responded are not formally trained in estimating; (54.2%, n=83/153).
- Outside of the IT Professional Services and Consulting Industry only 34.3% (n=24/70) of the population are formally trained in estimation.
- The majority of those who responded are experienced with six or more years experience in estimation; (80.4%, n=123/53).
- 53% (n=44/86) of respondents estimating projects for 10+ years have not been formally trained in estimation.

2.2 Research Question 2 Results

RQ2: Do Organisations have a Mature and Repeatable Estimating Process?

Figure 2-v - Organisations with a Defined Estimation Process

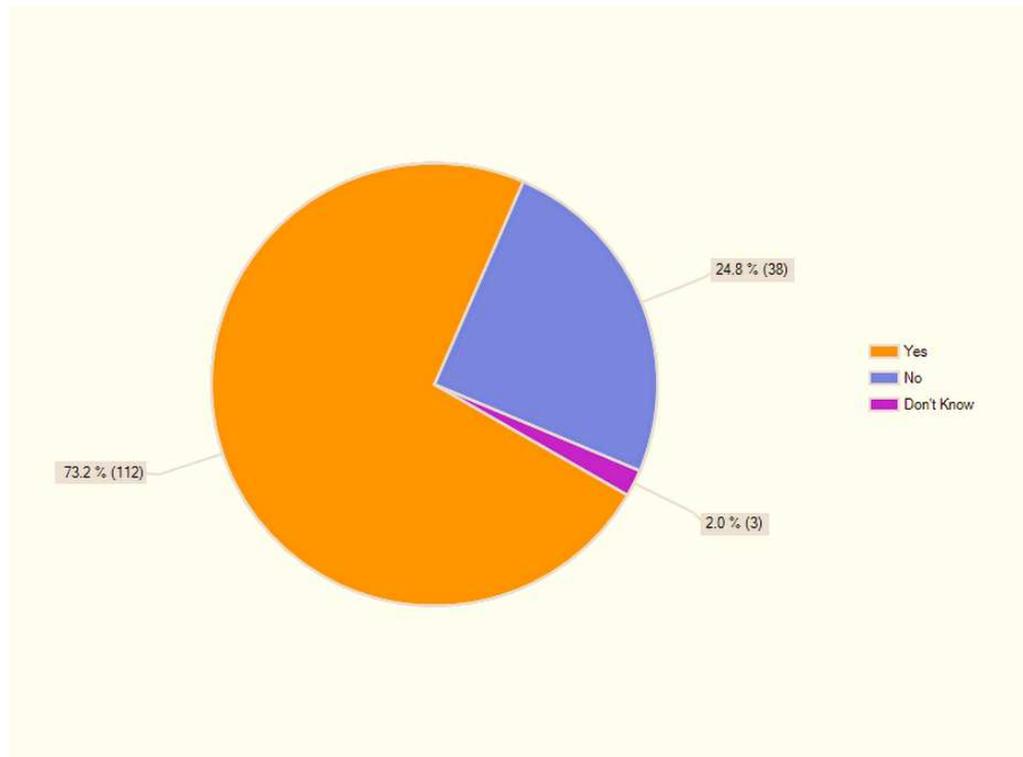


Figure 2-vi - Estimation Process Based on a Recognised Method

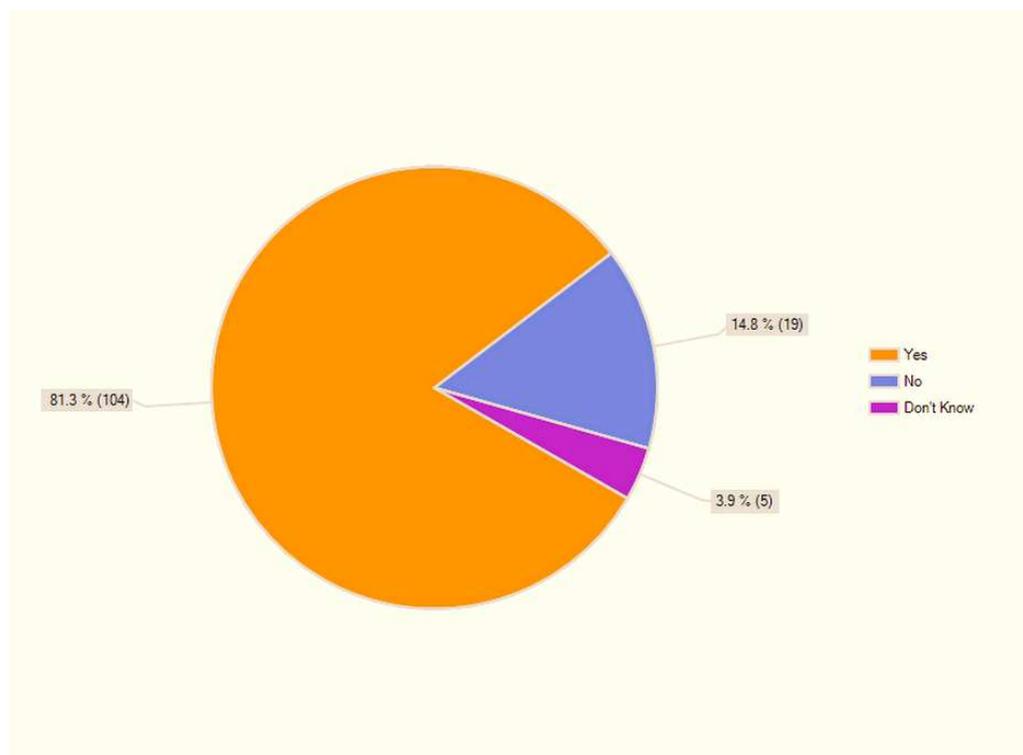


Figure 2-vii - Percentage of Staff who Follow the Official Approach

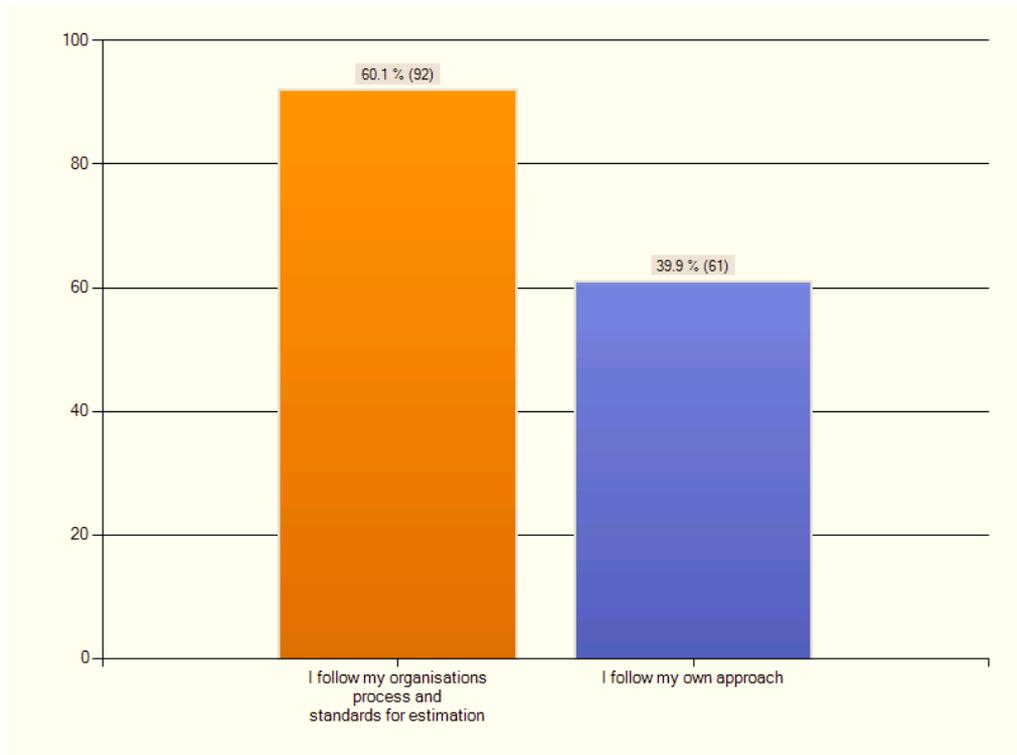


Figure 2-viii - Perceived Effectiveness of the Estimating Process Used

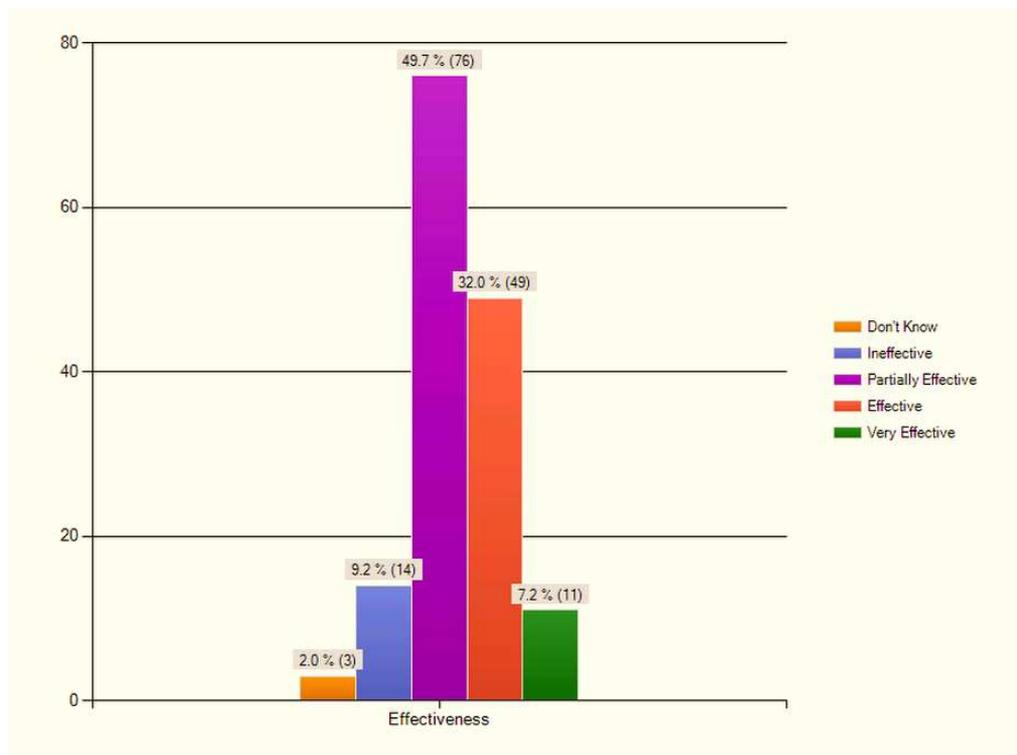


Figure 2-ix - Organisations with a Formal Estimating Team \ Function

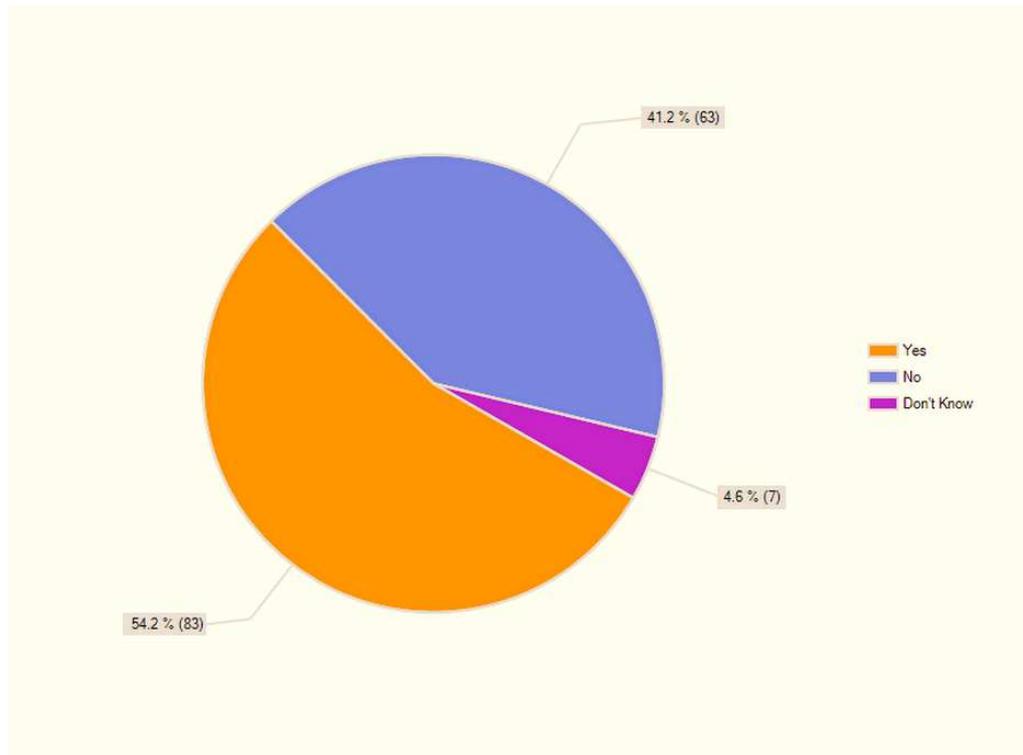


Figure 2-x - Conducted by Practitioners Trained in Estimating

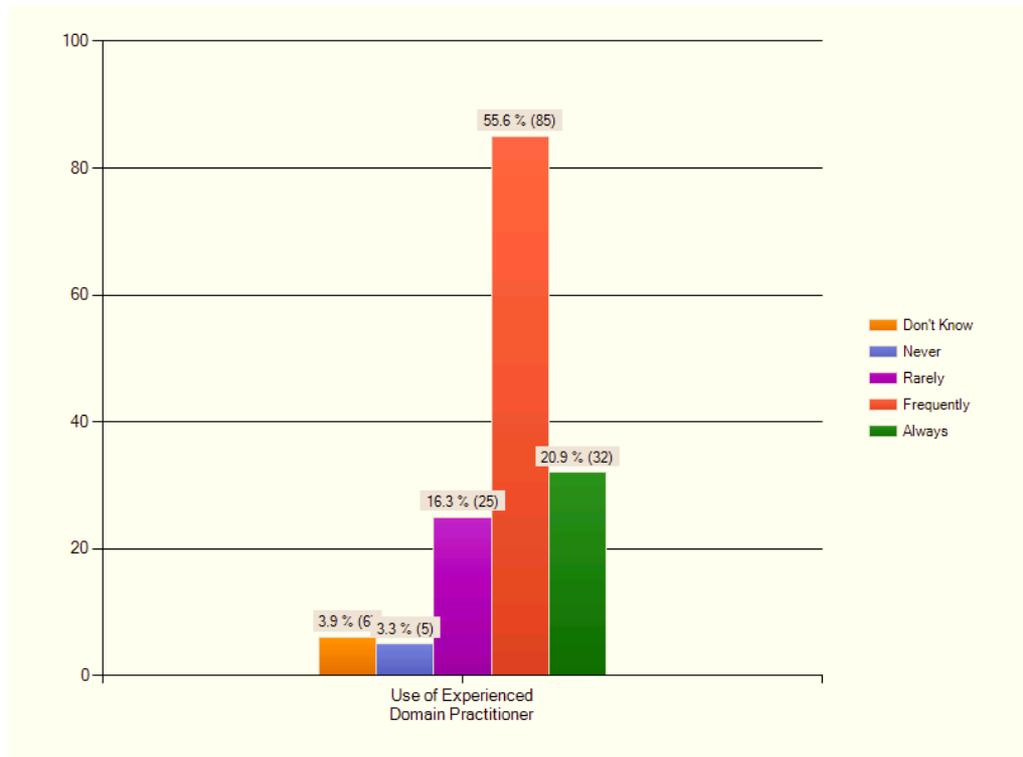


Figure 2-xi - Frequency of Capture of Historical Estimates

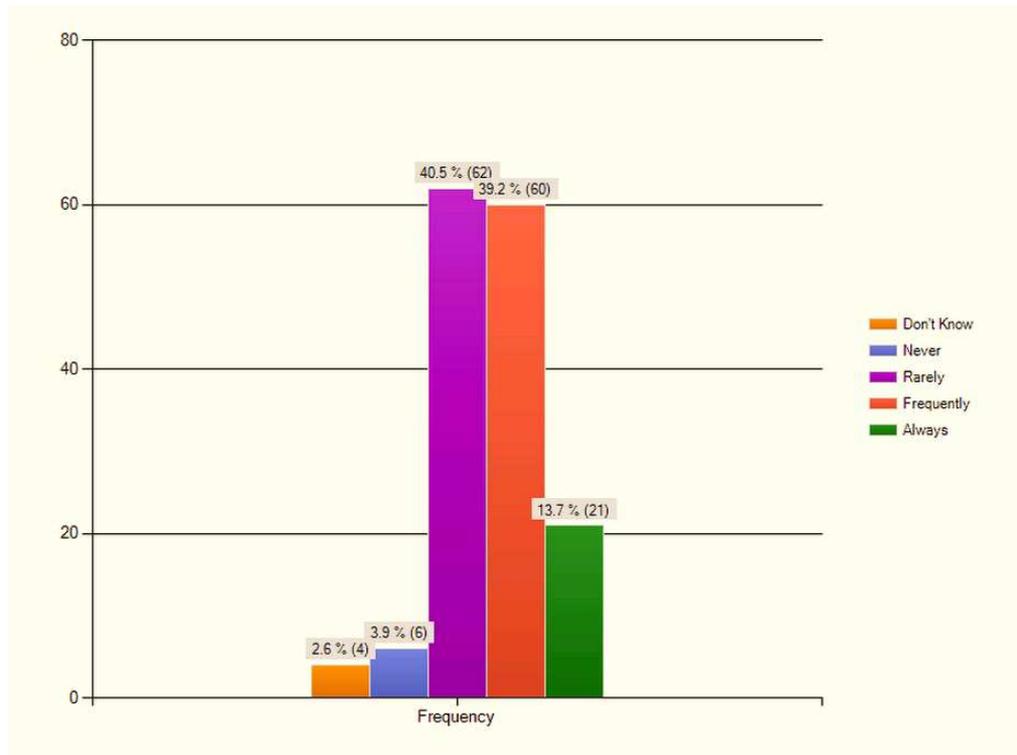


Figure 2-xii - Degree of Confidence in Historical Data

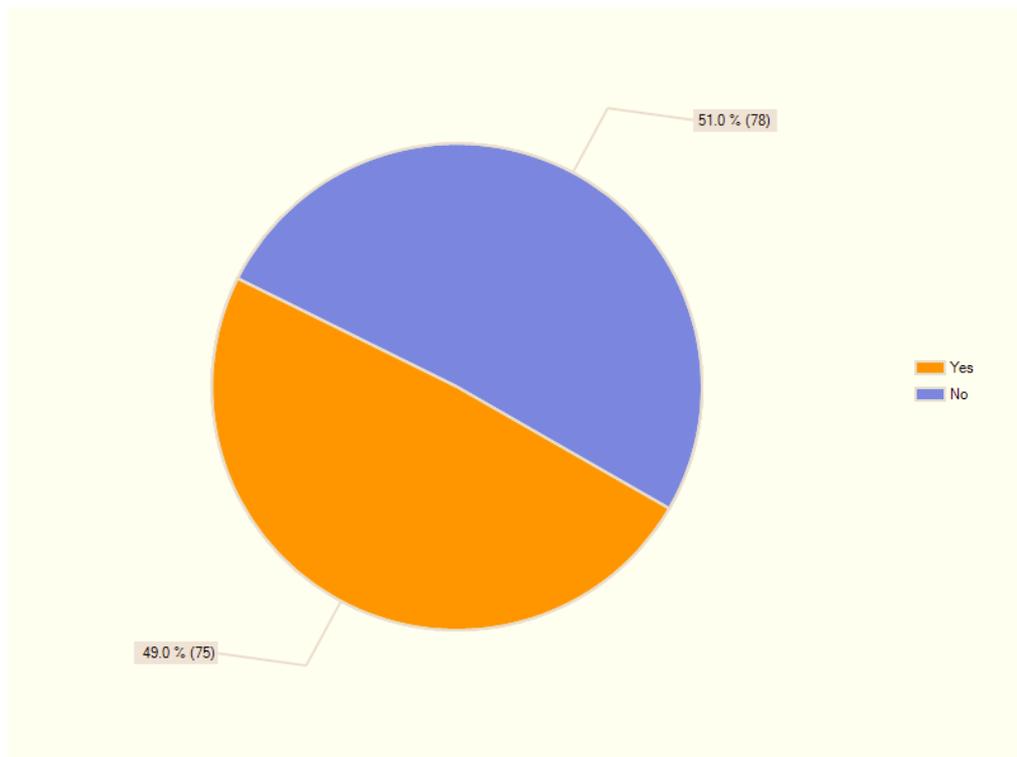


Figure 2-xiii - Accuracy & Usage of Estimating Tools

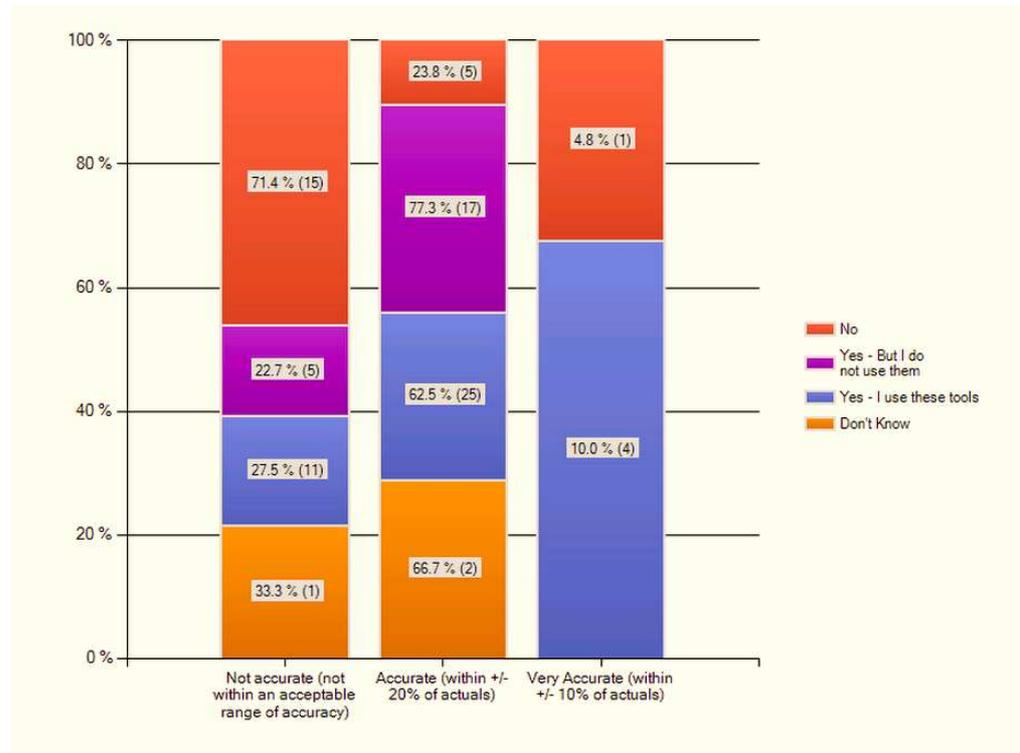
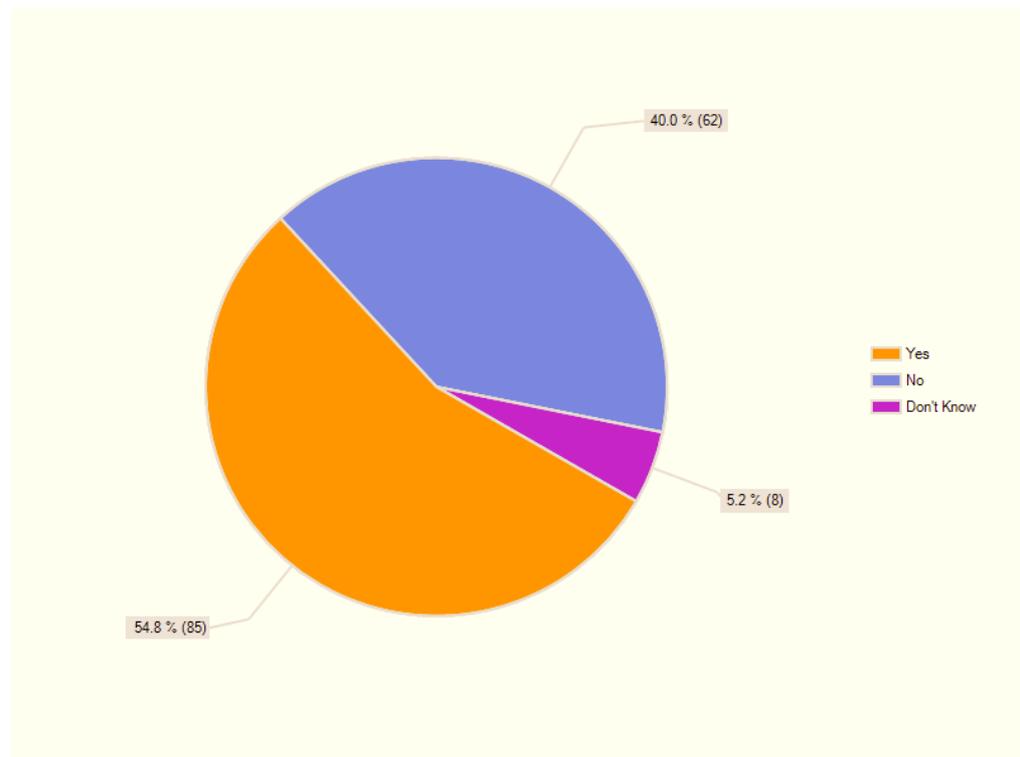


Figure 2-xiv - Practice of Comparing Effort Actuals versus Baseline



The key findings for this research question are:

- 24.8% (n=38/153) of organisations DO NOT have, or respondents are NOT AWARE of, a defined estimation process based on a recognised, documented and repeatable method or checklist for use in estimation in their organisation.
- 81.3% (n=104/153) of respondents report that their organisation's process is based on a recognised method.
- Of the 73.2% of organisations that do have a defined estimation process, 60.1% (n=92/153) of respondents use the estimation process. This leaves a significant proportion of estimators (39.9%, n=61/153) who do not follow their organisation's official estimation approach.
- Combining the results from the responses that do not have, or don't know of a recognised method in their organisation and the results of respondents that do not use their organisations official approach, this gives a total of 102 respondents or 66% of the total sample population who are not following a formal estimation process.
- 60.9% (n=93/153) of respondents DON'T KNOW how effective their organisation's estimating process is or perceive it to be INEFFECTIVE or PARTIALLY INEFFECTIVE.
- 54.2% (n=83/153) of organisations have a person or group with a defined role to develop, train and maintain standards in estimating within the organisation.
- 41.2% (n=63/153) of organisations do not have a person or group with a defined role to develop train and maintain standards in estimating within the organisation.

- 76% (n=117/153) report that estimation is frequently or always conducted by practitioners trained in estimating.
- 44% of respondents (n=68/153) state their organisation NEVER or RARELY collects historical estimates. 13.7% (21/153) report that historical estimates are always collected.
- 51% (n=78/153) of respondents have confidence in the historical actuals that the organisation has collected.
- Cross-tabulated data illustrates that 26% of respondents (n=40/153) use estimating tools to support effort estimation or uncertainty analysis (e.g. Monte Carlo analysis).
- 27.5% (n=11/153) of these tool users do not find the tools within an acceptable range of accuracy, 62.5% (n=25/153) find the tools within +/- 20% of actuals) and 10% (4) find them very accurate (within +/- 10% of actuals).
- 40% (n=62/153) of organisations do not compare their baseline effort estimates with their actual effort and record lessons learned.

2.3 Research Question 3 Results

RQ3: Is There A Culture Of Accountability For Estimating?

Figure 2-xv - Estimate Accountability Culture

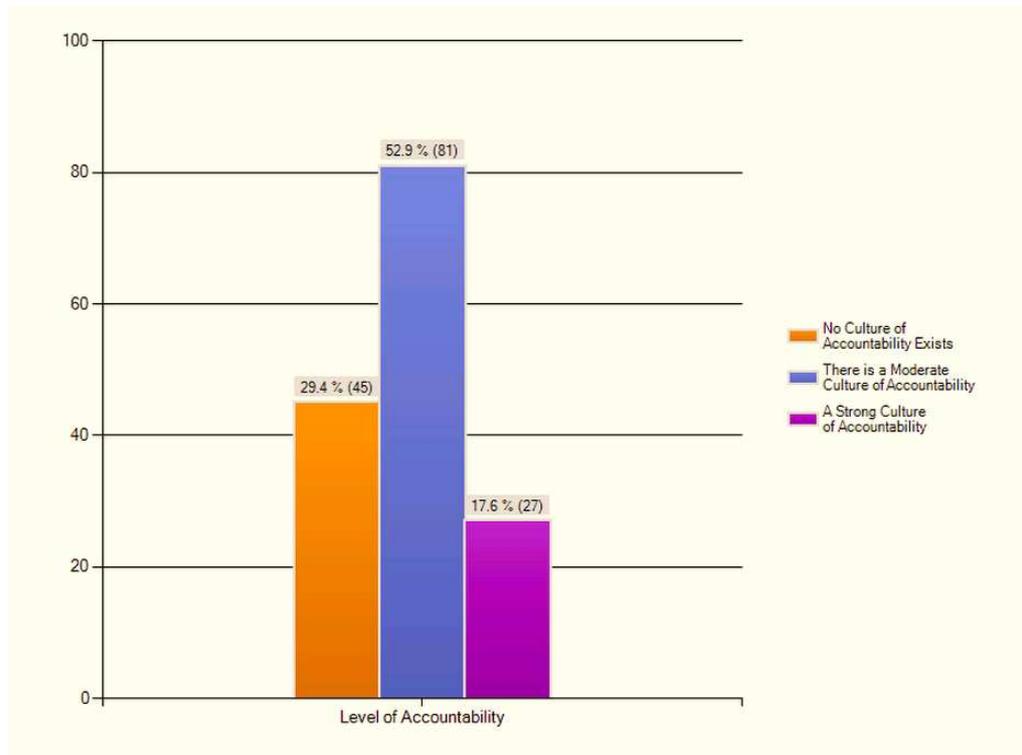
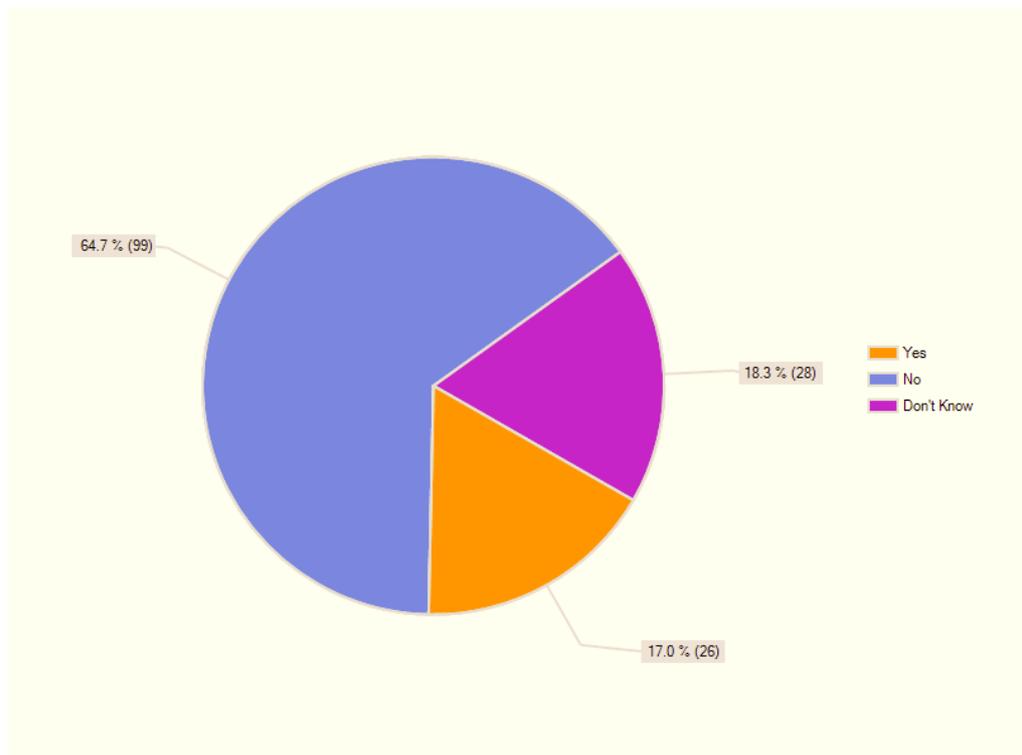


Figure 2-xvi - Performance Appraisal of Estimators



The key findings for this research question are:

- 17.6% (n=27/153) believe that there is a strong organisational culture of making the estimator accountable for the quality of their estimating.
- 52.9% (n=81/153) believe that there is a moderate organisational culture of making the estimator accountable for the quality of their estimating.
- 64.7% (n=99/153) report that estimating accuracy or robustness does not form part of the performance appraisal of estimators.

2.4 Research Question 4 Results

RQ4: Which Estimating Practices Are In Common Use?

Figure 2-xvii - Adjustment of Effort for Scope Uncertainty

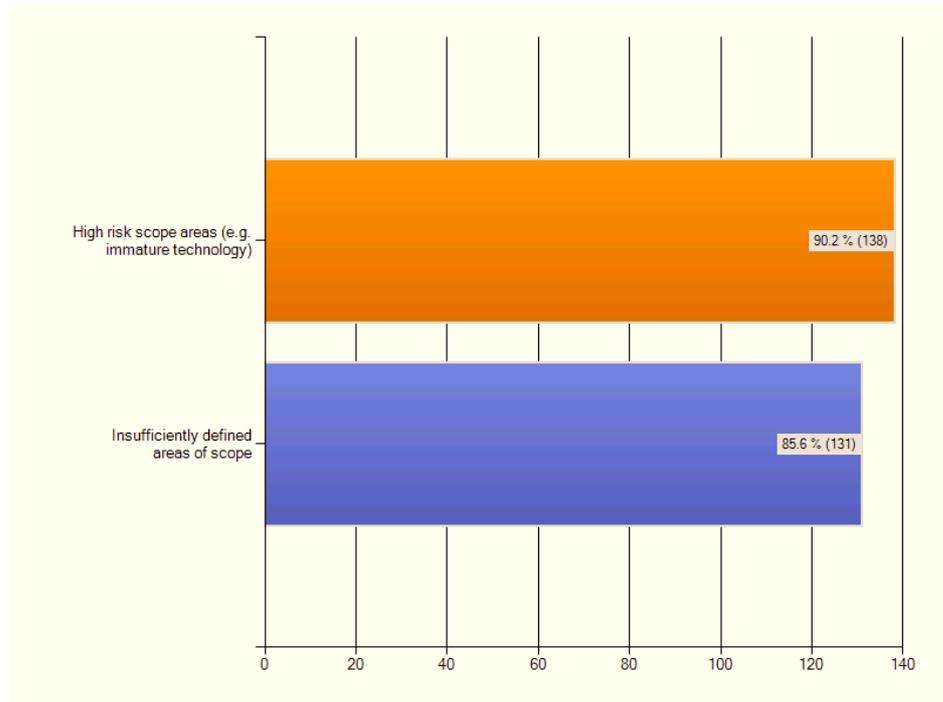


Figure 2-xviii - Risk Analysis Undertaken of Estimate

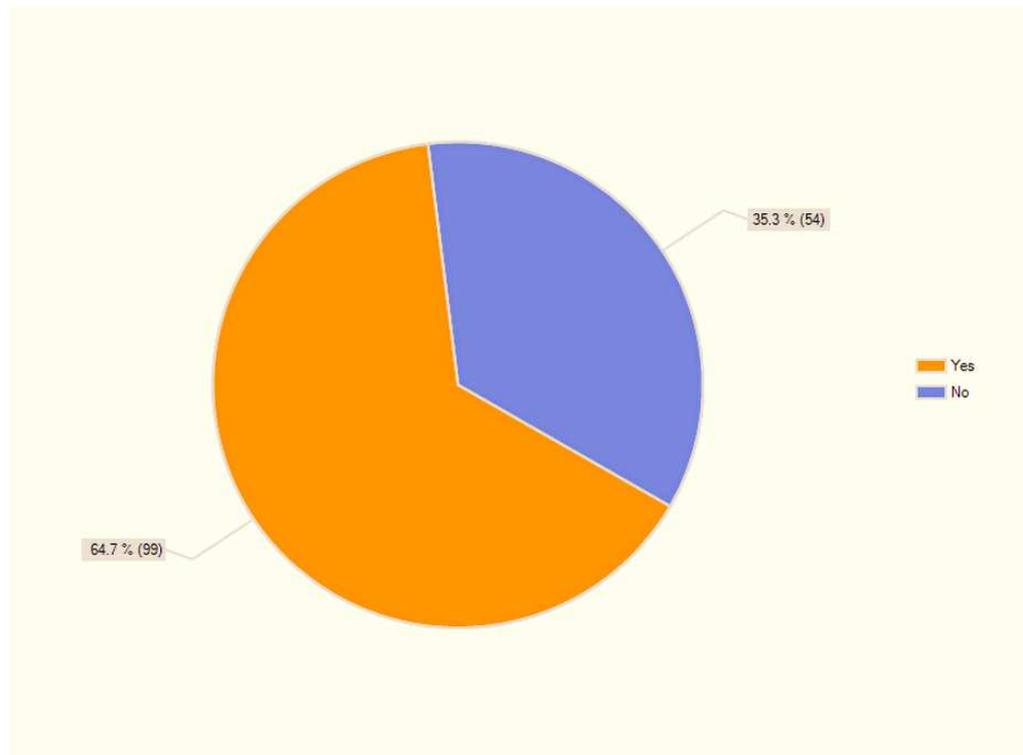


Figure 2-xix - Adjustment of Effort Resulting from Risk Assessment

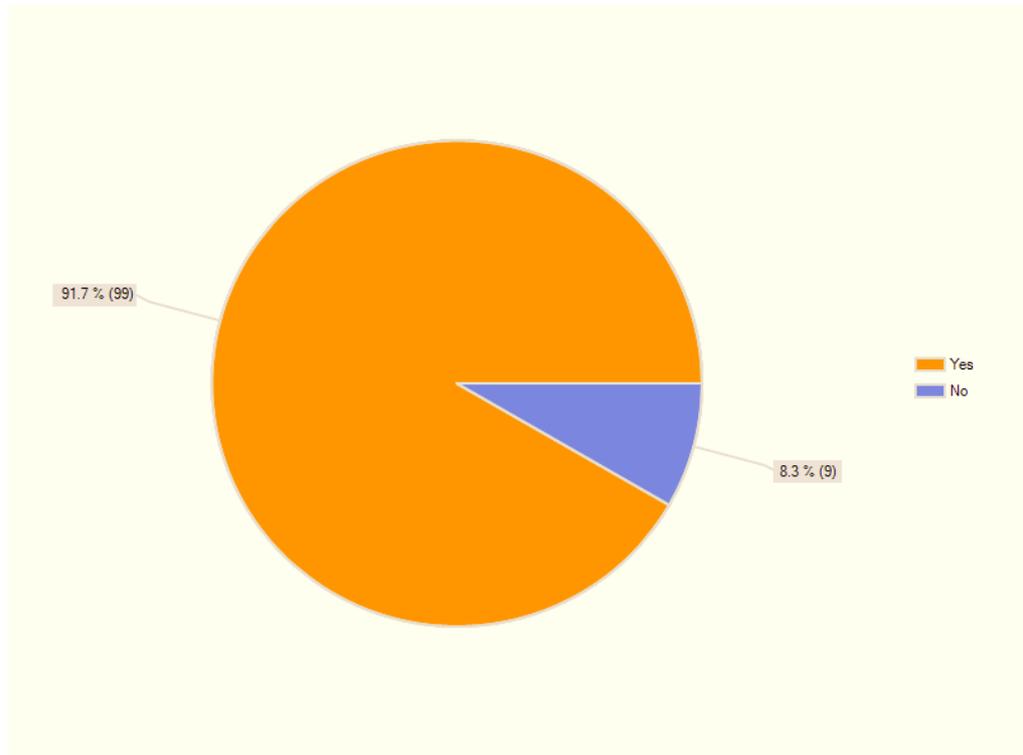


Figure 2-xx - Adjustment of Effort for Productivity

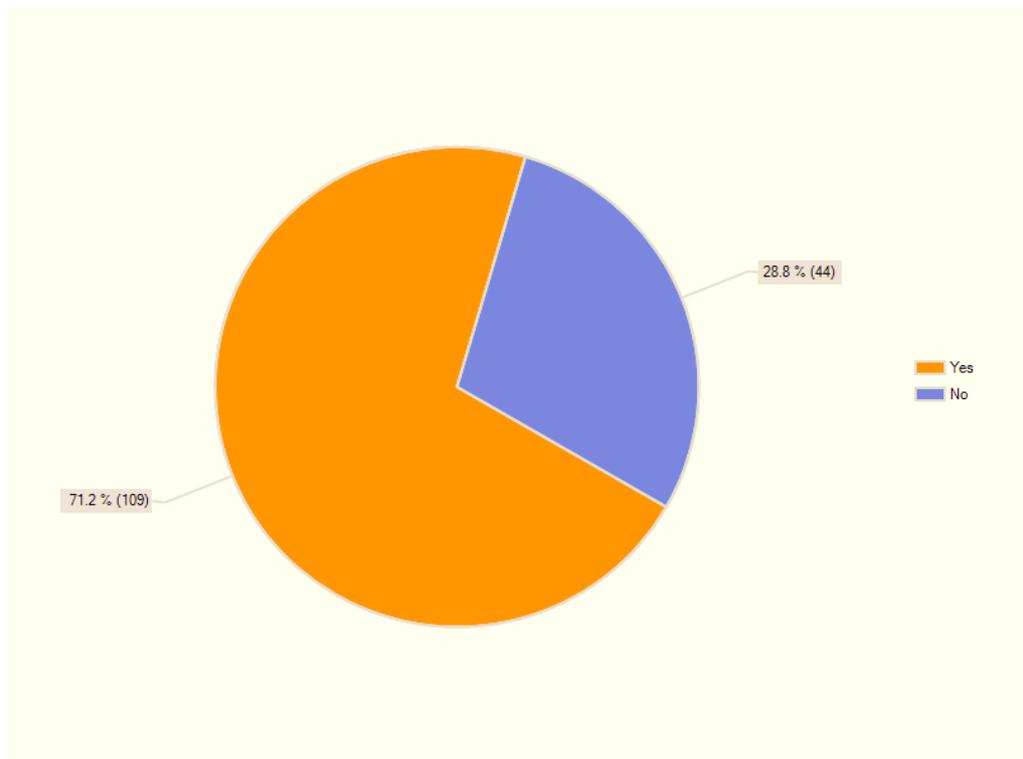


Figure 2-xxi - Adjustment of Effort for Resource Levelling

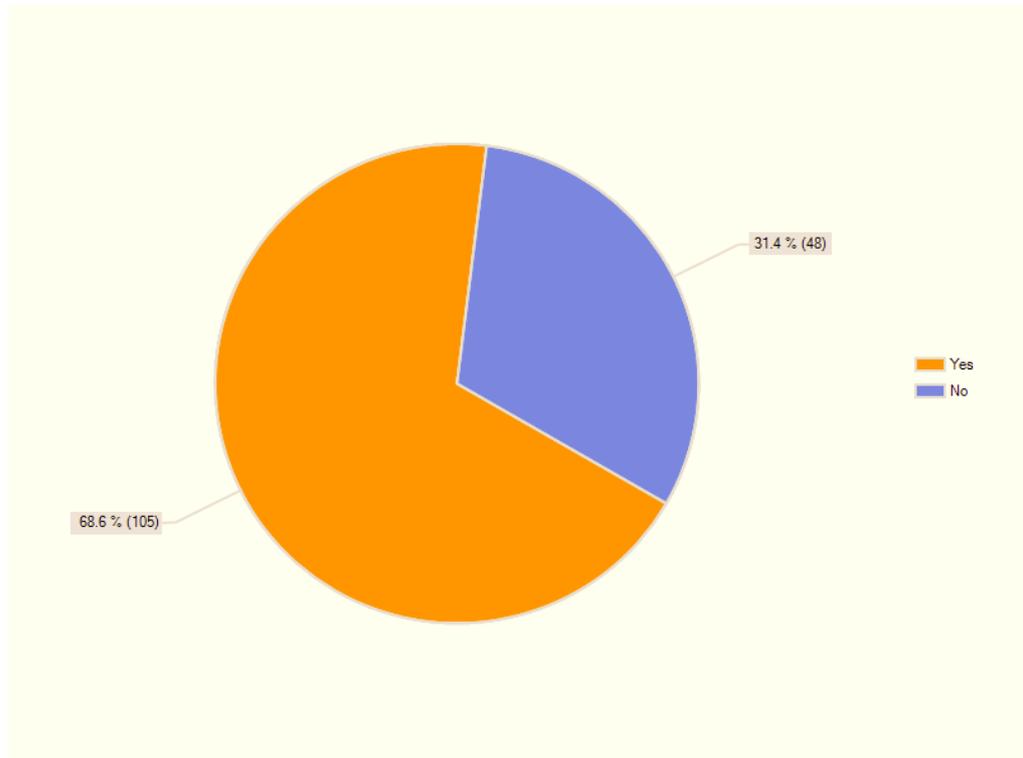


Figure 2-xxii - Documented Estimate Baseline & Assumptions

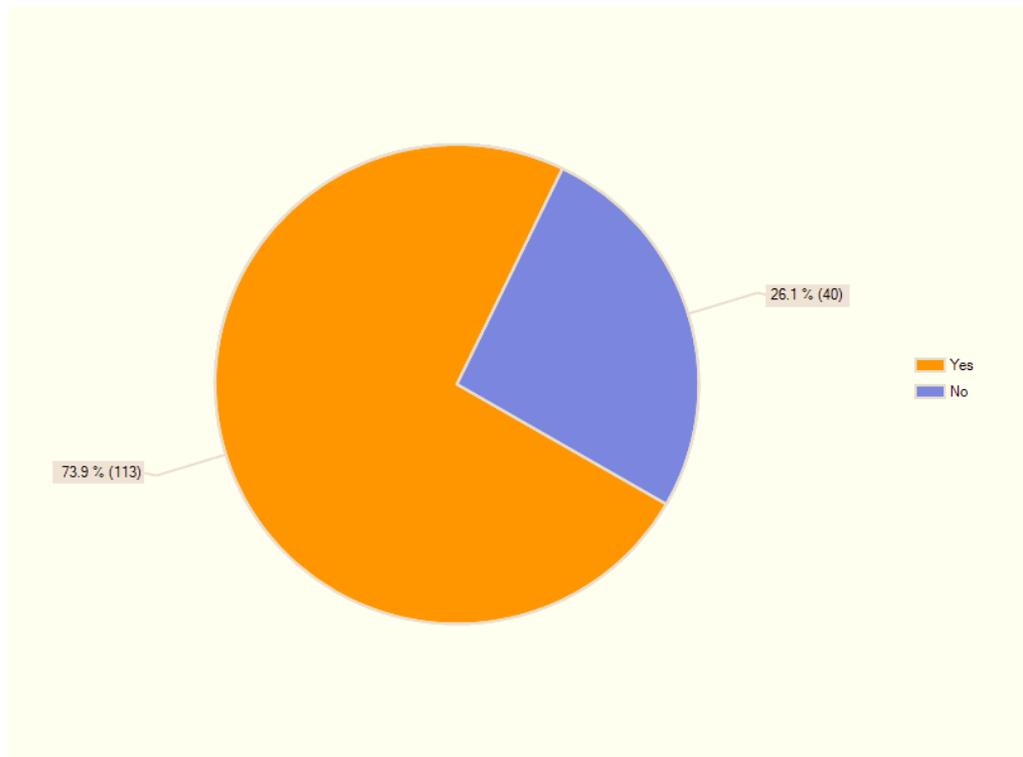


Figure 2-xxiii - Maintenance of a Central Repository of Estimates

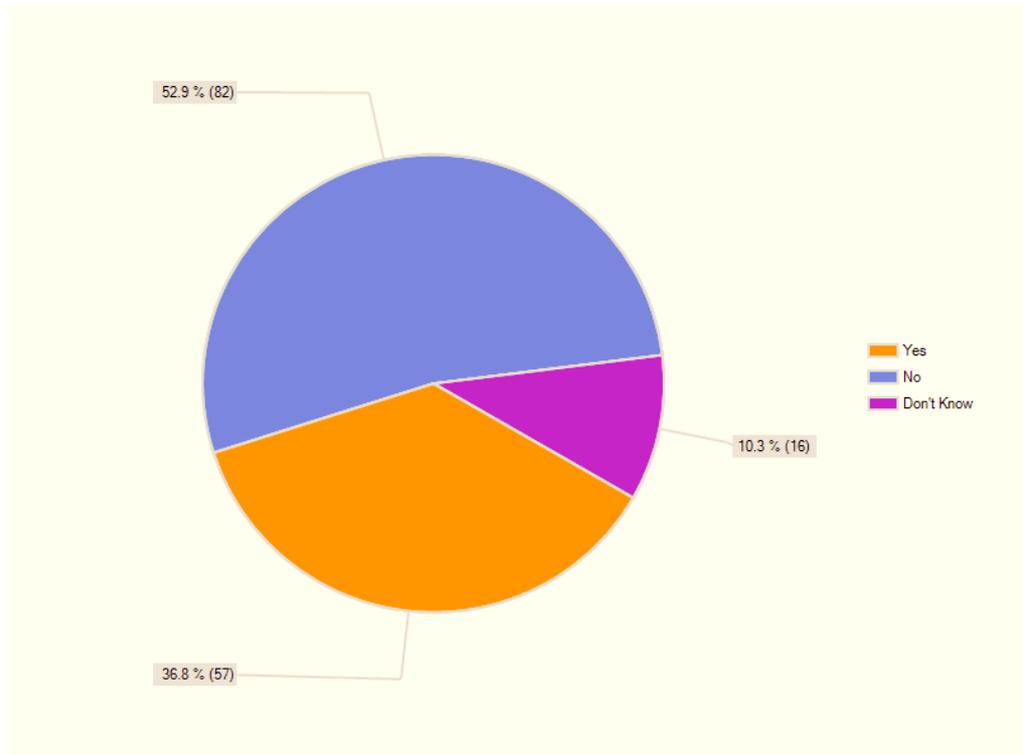


Figure 2-xxiv - Regular Re-estimation of Baseline

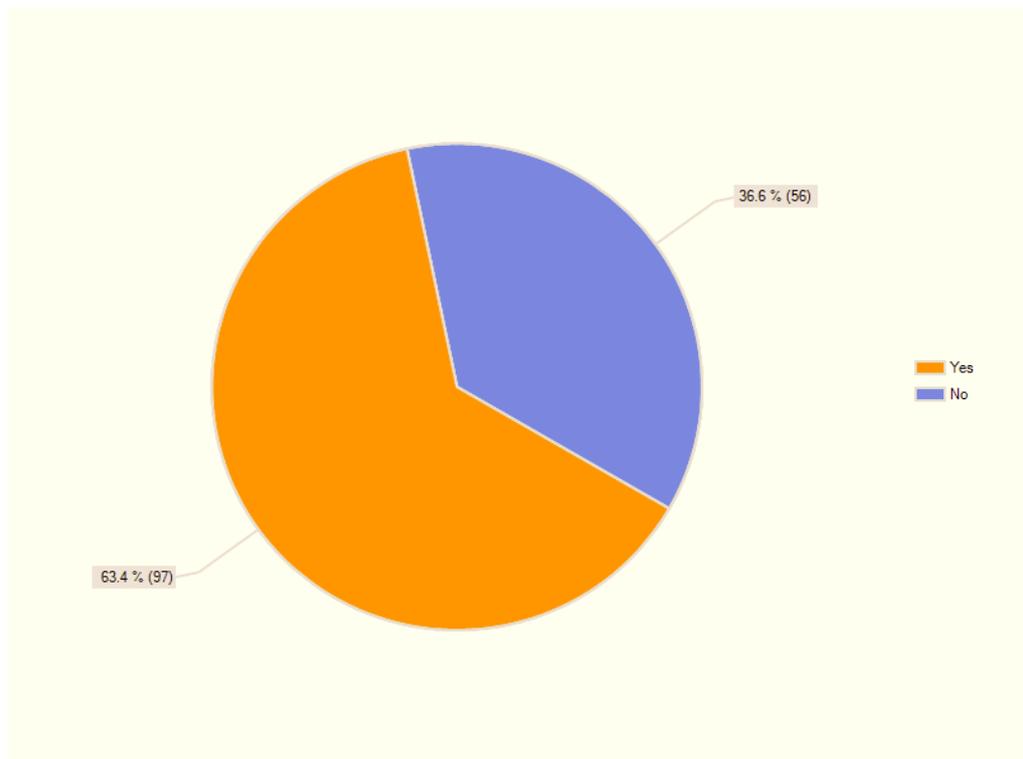


Figure 2-xxv - Independent Review of Estimate Conducted

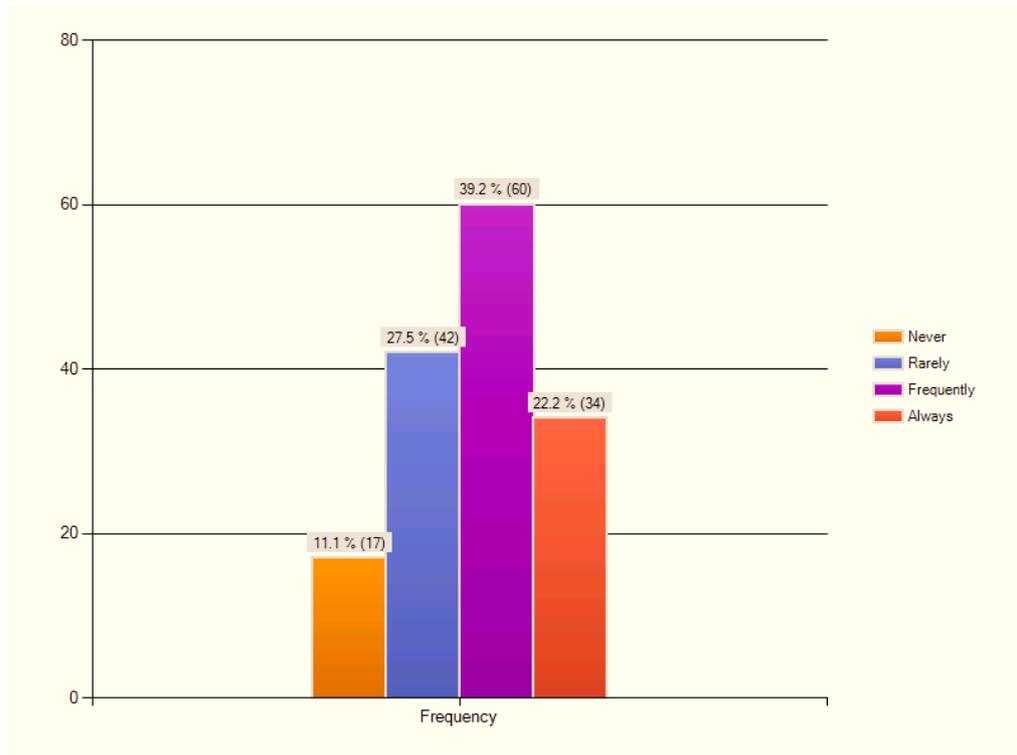


Figure 2-xxvi - Application of Contingency

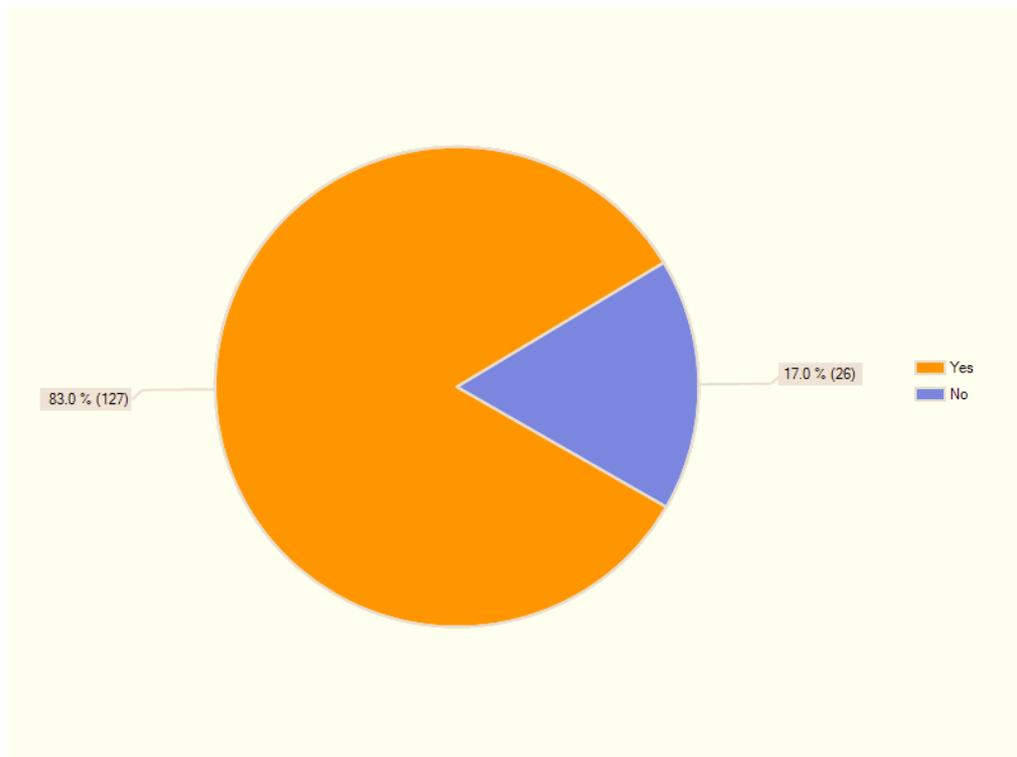


Figure 2-xxvii - Adjustment of Effort for Schedule Compression

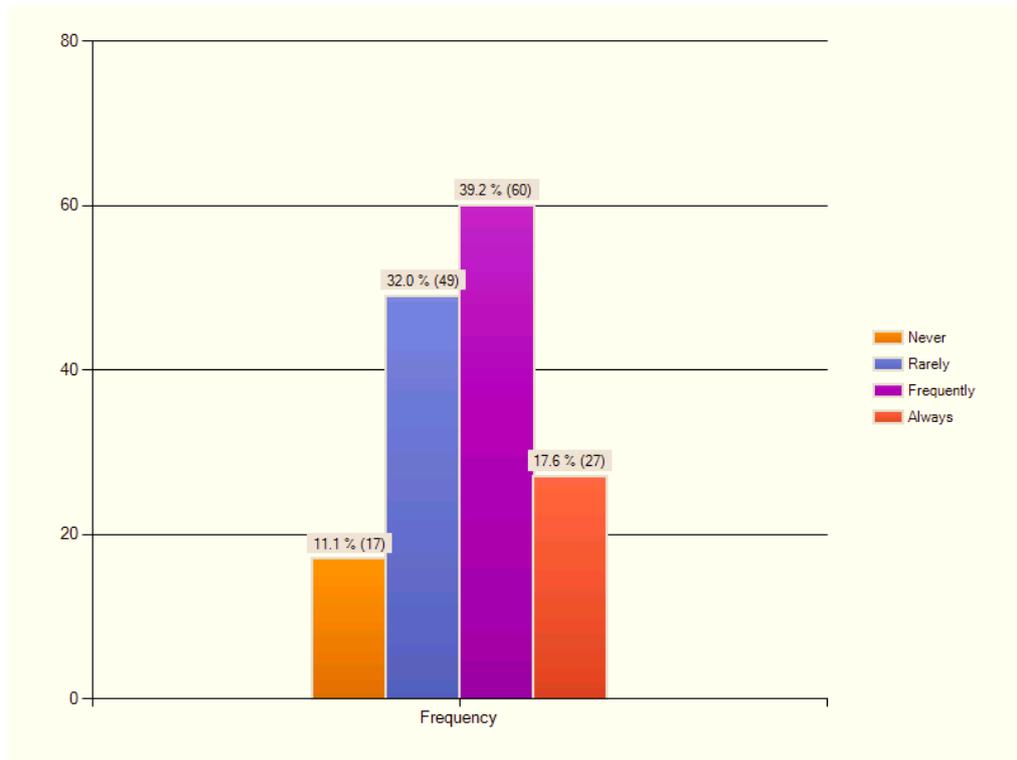


Figure 2-xxviii - Categories of Effort Included

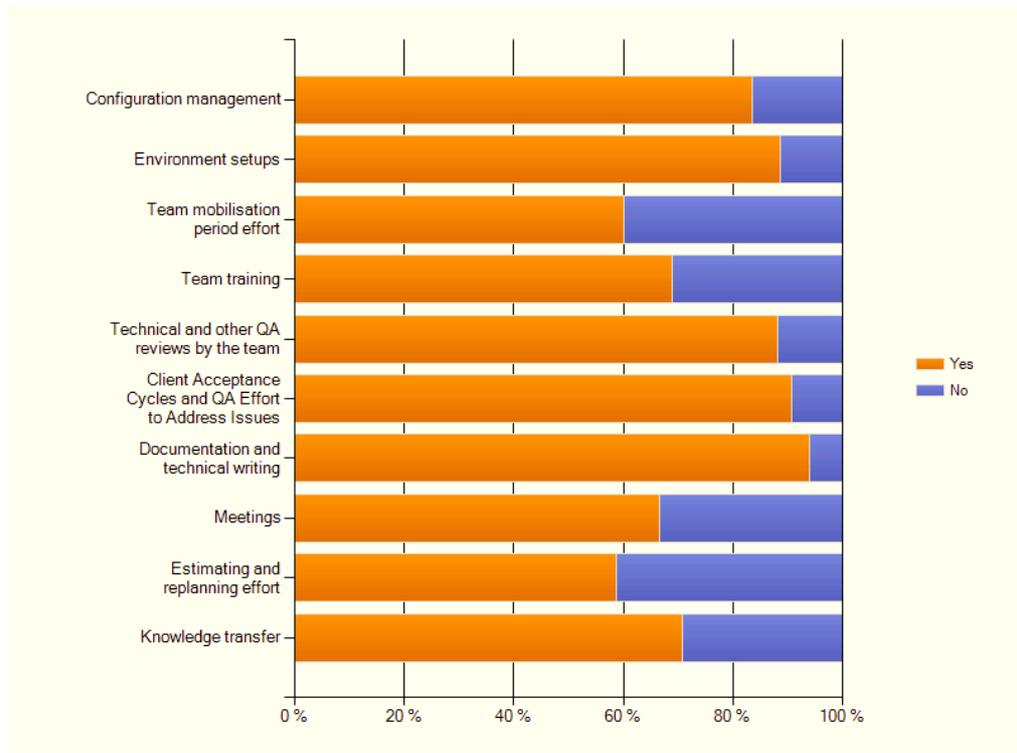
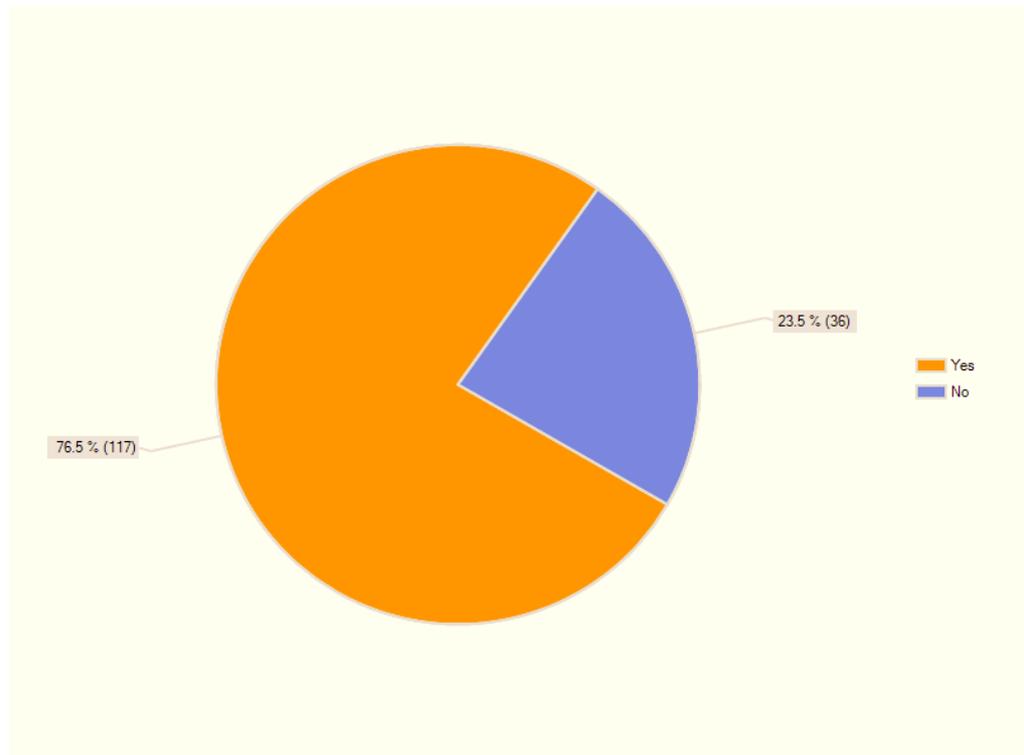


Table 2-i - Categories of Effort Included

Do you include effort for the following in your estimate?			
Answer Options	Yes	No	Response Count
Documentation and technical writing	94.1% (143)	5.9% (9)	152
Client Acceptance Cycles and QA Effort to Address Issues	90.8% (138)	9.2% (14)	152
Environment setups	88.7% (134)	11.3% (17)	151
Technical and other QA reviews by the team	88.1% (133)	11.9% (18)	151
Configuration management	83.6% (127)	16.4% (25)	152
Knowledge transfer	70.7% (106)	29.3% (44)	150
Team training	68.9% (104)	31.1% (47)	151
Meetings	66.7% (100)	33.3% (50)	150
Team mobilisation period effort	60.1% (89)	39.9% (59)	148
Estimating and re-planning effort	58.7% (88)	41.3% (62)	150
Total Population			153

Figure 2-xxix - Inclusion of Level of Effort Tasks \ Duration Based Roles



The key findings for this research question are:

- Estimators report that the following items are not included in their estimate:
- 41.3% (n=62/150) do not include effort required for estimating and re-planning their project;
- 39.9% (n=59/148) do not include effort for team mobilisation;
- 33.3% (n=50/150) do not include effort for meetings;
- 31.1% (n=47/151) do not include effort for team training;
- 29.3% (n=44/150) do not include effort for knowledge transfer.
- 35.3% (n=54/153) of estimators do not adjust their estimate for known-unknown and unknown-unknown risks.
- 96% (n=95/99) of those who do undertake a risk assessment do adjust the effort estimate based on their risk assessment.
- 28.8% (n=44/153) do not adjust their effort sizing to take into account the different productivity levels of different resources, i.e. higher effort estimates for tasks undertaken by less experienced or less skilled staff.
- Only 17.6% (n=27/153) adjust their project effort when they compress the baseline project schedule.
- 31.4% (n=48/153) do not level their resourcing using a standard working day and when resources are overloaded.

- 36.6% (n=56/153) of estimators do not regularly re-estimate their project at milestones or regularly intervals, e.g. weekly or monthly.
- 26.1% (n=40/153) of estimators stated they do not maintain a documented estimate baseline with assumptions throughout the lifecycle of the estimate creation process.
- 36.8% (n=57/153) of estimators stated NO and 10.3% (n=16/153) stated DON'T KNOW as to whether their organisation maintains a central organisation-wide repository of all baseline estimates including assumptions.
- The majority of estimators adjust their estimates for scope uncertainty such as new technology; (90.2%, n=138/153) and insufficiently defined areas of scope; (85.6%, n=131/153).
- The majority of estimators (83%, n=127/153) apply contingency to their estimates.
- The majority of estimators 76.5% (117/153) identify Level of Effort (LoE) tasks and the corresponding Duration Based Roles (DBR) and include these in their base estimate.
- The majority of estimates undergo independent review with 39.2% (n=60/153) doing so FREQUENTLY and 22.2% (n=34/153) ALWAYS undertaken.

2.5 Research Question 5 Results

RQ5: Which Estimating Techniques Or Formal Models Are Used?

Table 2-ii - Estimation Approaches and Techniques in Use

Which estimating techniques or formal models do you use and how often?					
Answer Options	Never	Rarely	Frequently	Always	Response Count
None	77.6% (52)	11.9% (8)	9% (6)	1.5% (1)	67
Bottom Up Activity Based (WBS)	7.5% (11)	9.5% (14)	66.7% (98)	16.3% (24)	147
Expert Judgement (Individuals)	2.1% (3)	8.3% (12)	66.2% (96)	23.4% (34)	145
Expert Judgement in Groups (e.g. Wide Band Delphi)	21.7% (28)	36.4% (47)	34.1% (44)	7.8% (10)	129
Analogy / Compare to Similar Projects	2.9% (4)	13.7% (19)	67.6 (94)	15.8% (22)	139
Formal Models - Non Product Specific Models (e.g. Putnam, Monte Carlo, Function Points)	52.4% (65)	26.6% (33)	14.5% (18)	6.5% (8)	124
Formal Models - Product Specific (e.g. for SAP, Oracle, EAI products, etc)	48.4% (45)	25.8% (24)	22.6% (21)	3.2% (3)	93
Heuristics (Rules of Thumb)	14.3% (19)	15.8% (21)	59.4% (79)	10.5% (14)	133
PERT	32.5% (40)	24.4% (30)	39% (48)	4.1% (5)	123
Other	87.5% (49)	0% (0)	8.9% (5)	3.6% (2)	62
Total Population					153

Figure 2-xxx - Estimation Approaches and Techniques in Use

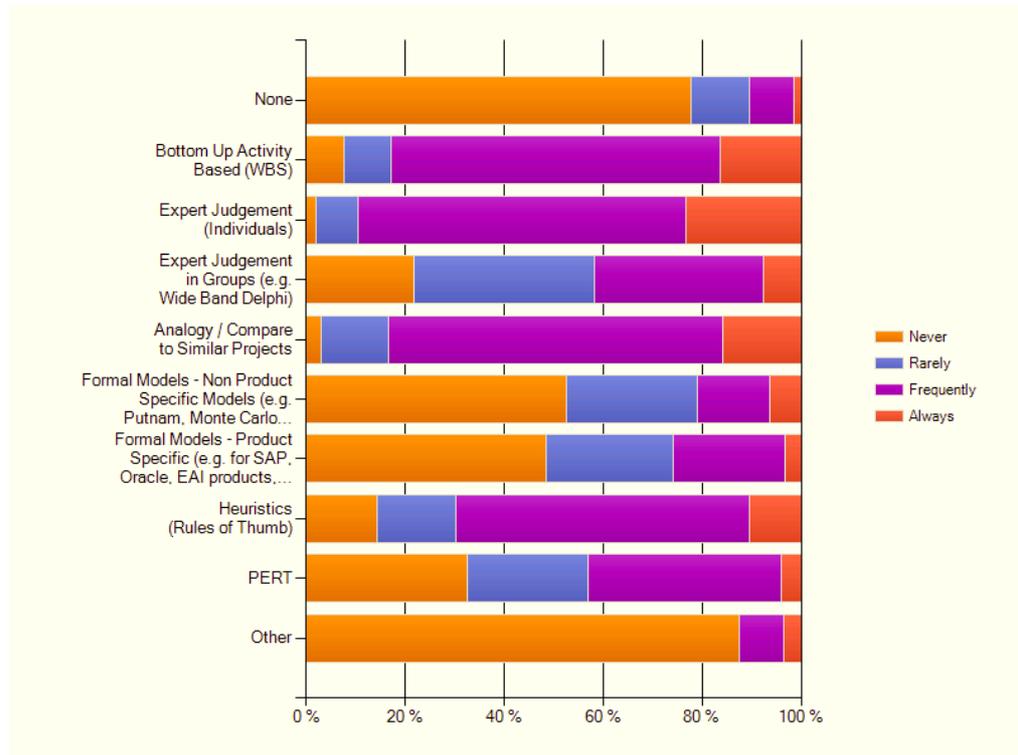
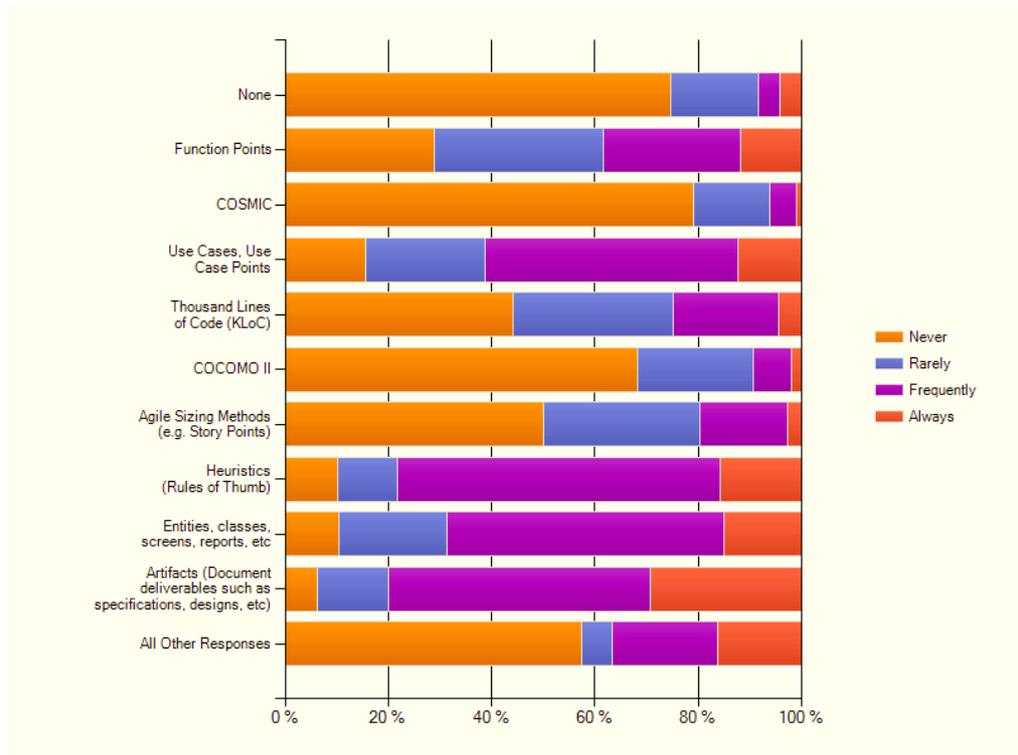


Figure 2-xxxi - Approaches Used to Size Projects



The key findings for this research question are:

- The estimation approaches reported as FREQUENTLY used are (1) Analogy; (67.6%, n=94/139), (2) Bottom Up Activity Estimation; (66.7%, n=98/147), (3) Individual Expert Judgement; (66.2%, n=96/145) and (4) Rules of Thumb; (59.4%, n=79/133) and (5) 39.2% (n=60/153) do not use any of the estimating techniques listed.
- Individual expert judgement is ALWAYS used in 23.4% (n=34/145) of cases whilst formal models, both product specific and generic are used in 3.2% (n=3/93) and 6.5% (n=8/124) of cases respectively.
- Group expert judgement is FREQUENTLY used in 66.2% (n=96/145) of cases and ALWAYS in 23.4% (n=34/145) of cases.
- Formal models, both product specific or generic have low usage and are reported as NEVER used in 48.4% (n=45/93) and 52.4% (n=65/124) of responses respectively and RARELY in 25.8% (n=24/93) and 26.6% (=33/124) of cases.
- Rules of thumb; (62.5%, n=80/128), Entities, classes, screens, etc; (53.7%, n=72/134), Artefacts; (50.8%, n=66/130) and Use Cases; (48.8%, n=63/129) are FREQUENTLY used to derive a project's size.
- COSMIC; (79.2, n=76/96), COCOMO II; (68.2%, n=73/107), Agile Sizing Methods; (50%, n=56/112) and KLOC; (44.2%, n=50/113) are the least used methods for sizing a project.
- Function points are cited as more RARELY used (32.8%, n=42/128) than FREQUENTLY used (26.6%, n=34/128) to derive project size.
- Artefacts are cited the most as ALWAYS used (29.2%, n=38/130) to derive project size.

2.6 Research Question 6 Results

RQ6: Is Probability And Variance Of The Estimate Communicated?

Figure 2-xxxii - Estimates Provided with Probability Stated

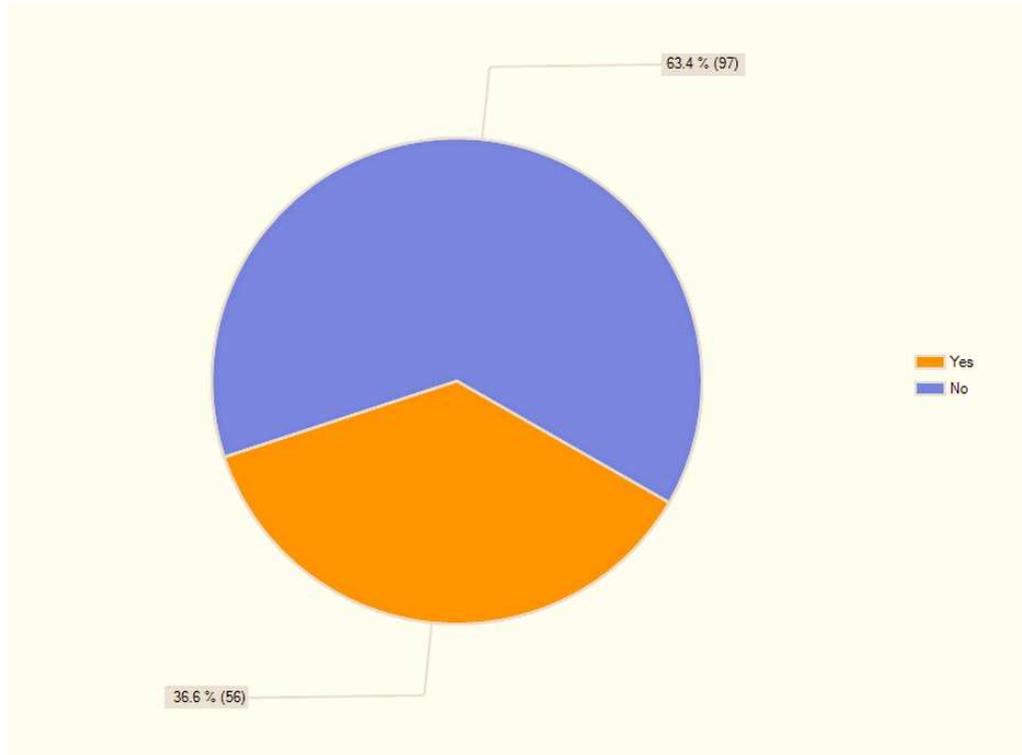
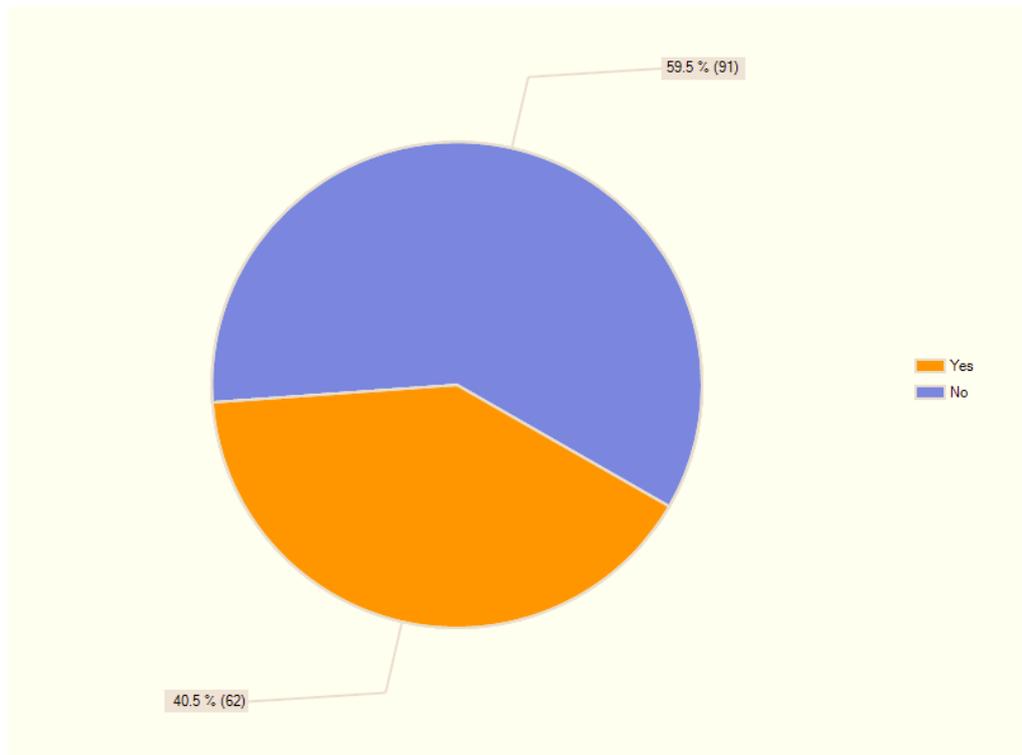


Figure 2-xxxiii - Estimates Provided with Variance Stated



The key findings for this research question are:

- 63.4% (n=97/153) of estimators do not specify the probability for achieving their estimates when communicating these to managers or clients.
- 59.9% (n=91/153) of estimators do not specify the variance or minimum - maximum range of which their estimate is within, when communicating their estimate to managers or clients.

2.7 Research Question 7 Results

RQ7: How Accurate Do Estimators' Believe They Are?

Figure 2-xxxiv - Estimator's Self Perception of Optimism

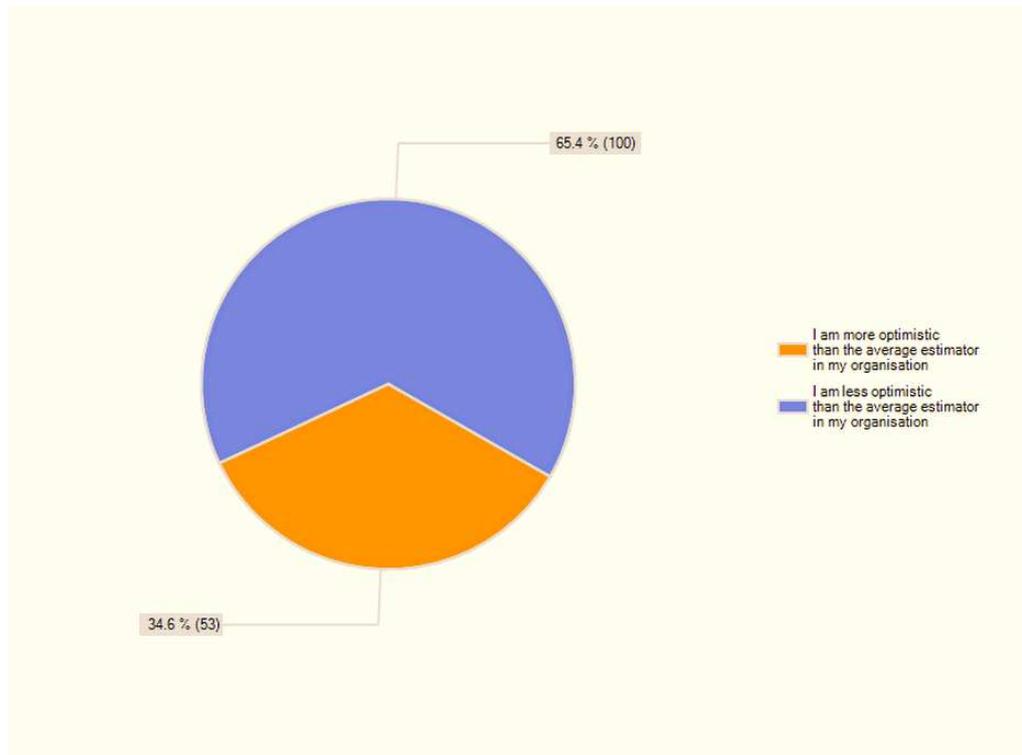
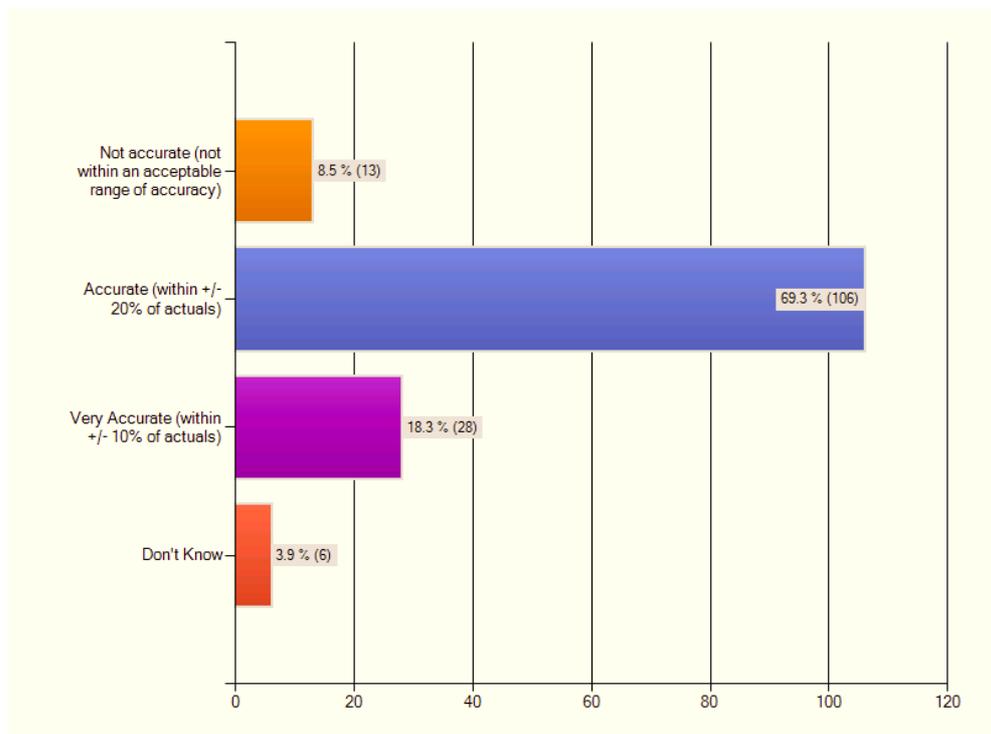


Figure 2-xxxv - Estimator's Self Perception of Accuracy



The key findings for this research question are:

- 65.4% (n=100/153) of estimators, in their own opinion, consider their estimates in the past have been less optimistic than the average estimator in their organisation.
- Very few estimators believe that their estimates in the past have been inaccurate; (8.5%, n=13/153).
- The majority of estimators 69.3% (n=106/153) believe that their estimates in the past are accurate within +/- 20% of the eventual outcome.
- 18.3% (n=28/153) of estimators believe that their estimates in the past are very accurate by being within +/- 10% of the eventual outcome.

2.8 Research Question 8 Results

RQ8: What Are the Factors That Influence an Estimator's Judgement in Sizing a Software Development Project?

Figure 2-xxxvi - Key Influences on Estimates – Area Chart

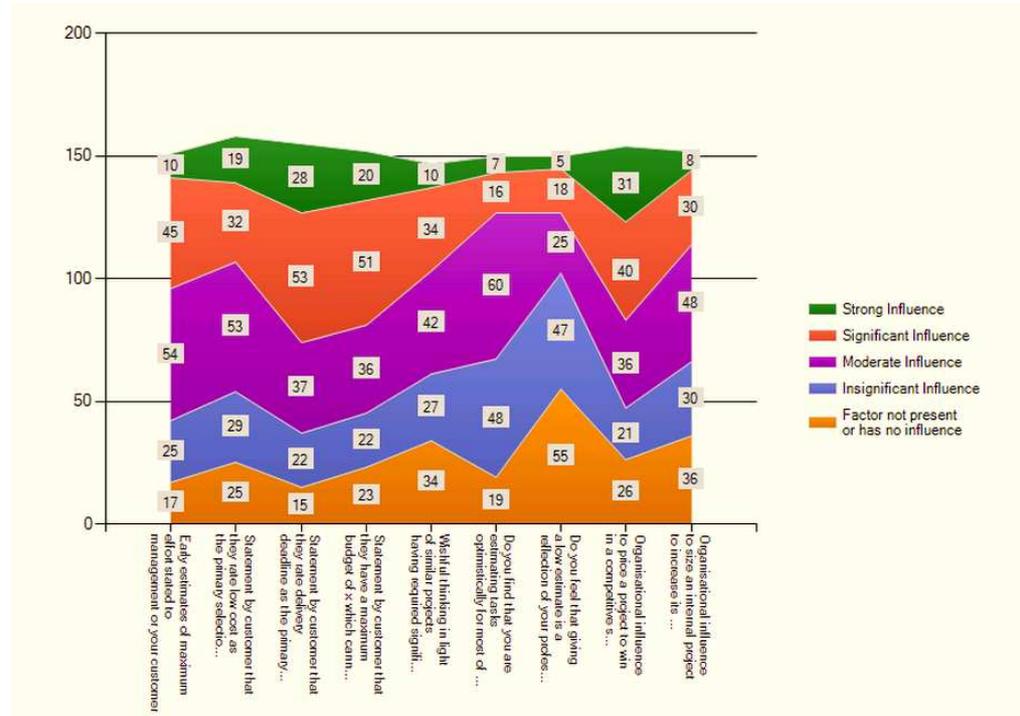
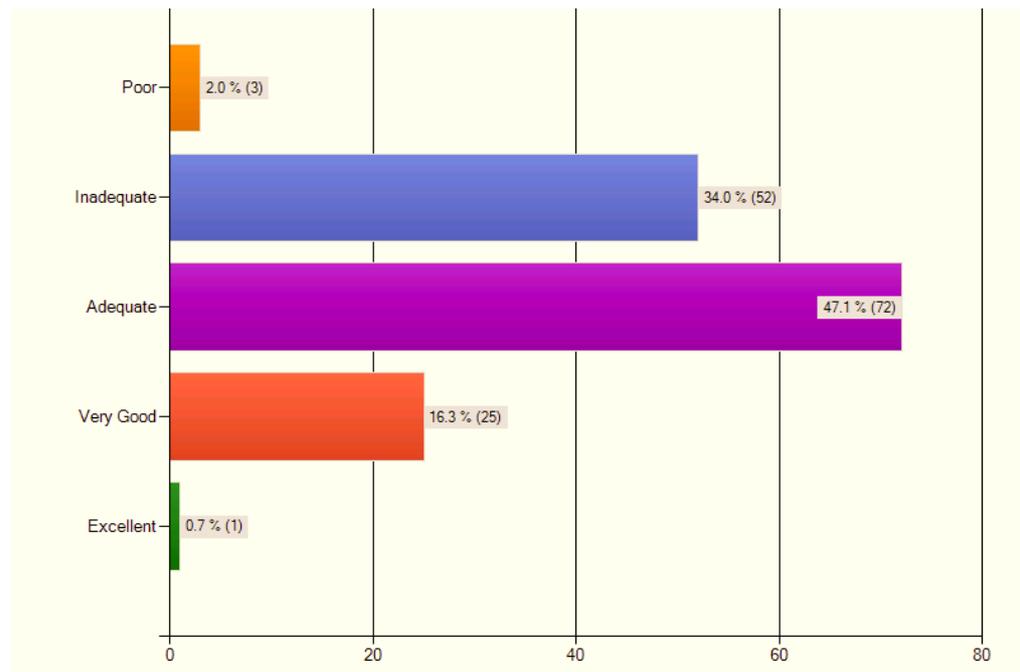


Figure 2-xxxvii - Quality of Requirements Baseline for Estimating



The key findings for this research question are:

- 36% (n=55/153) of estimators believe that their committed estimate is typically based on requirements that are POOR or INADEQUATE in their quality and completeness.
- 47.1% (n=72/153) of estimators believe that their committed estimate is typically based on requirements that are ADEQUATE in their quality and completeness.
- The minority of estimators, 17% (n=55/153) believe that their committed estimate is typically based on requirements that are VERY GOOD or EXCELLENT in their quality and completeness.
- Of those that responded, the majority of estimators identified the following influences or behaviours as INSIGNIFICANT or NOT a factor in having an influence on their baseline effort estimate:
- Giving a low estimate is a reflection of your professional ability to deliver to a commitment; NOT a factor (36.9%, n=55/149) and an INSIGNIFICANT factor (31.5%, n=47/149).
- Of those that responded, the majority of estimators identified the following influences or behaviours as a MODERATE factor or having an influence on their baseline effort estimate:
- Early estimates of maximum effort stated to management or the customer; 36.2% (n=54/149).
- Statement by customer that they rate low cost as the primary selection criterion; 34.6% (n=53/153).

- Wishful thinking in light of similar projects having required significantly more effort than what the estimator estimates; 28.6% (n=42/147).
- Estimator finds that they estimating task optimistically for most of their estimate; 40.5% (n=60/148).
- Organisational influence to size an internal project to increase its likelihood to be approved; 32.9% (n=48/146).
- Of those that responded, the majority of estimators identified the following influences or behaviours as a SIGNIFICANT factor or having an influence on their baseline effort estimate:
- Statement by customer that they rate delivery deadline as the primary selection criterion; 35.3% (n=53/150).
- Statement by customer that they have a maximum budget of x which cannot be exceeded; 34.2% (n=51/150).
- Organisational influence to price a project to win in a competitive situation; 26.2% (n=40/141).

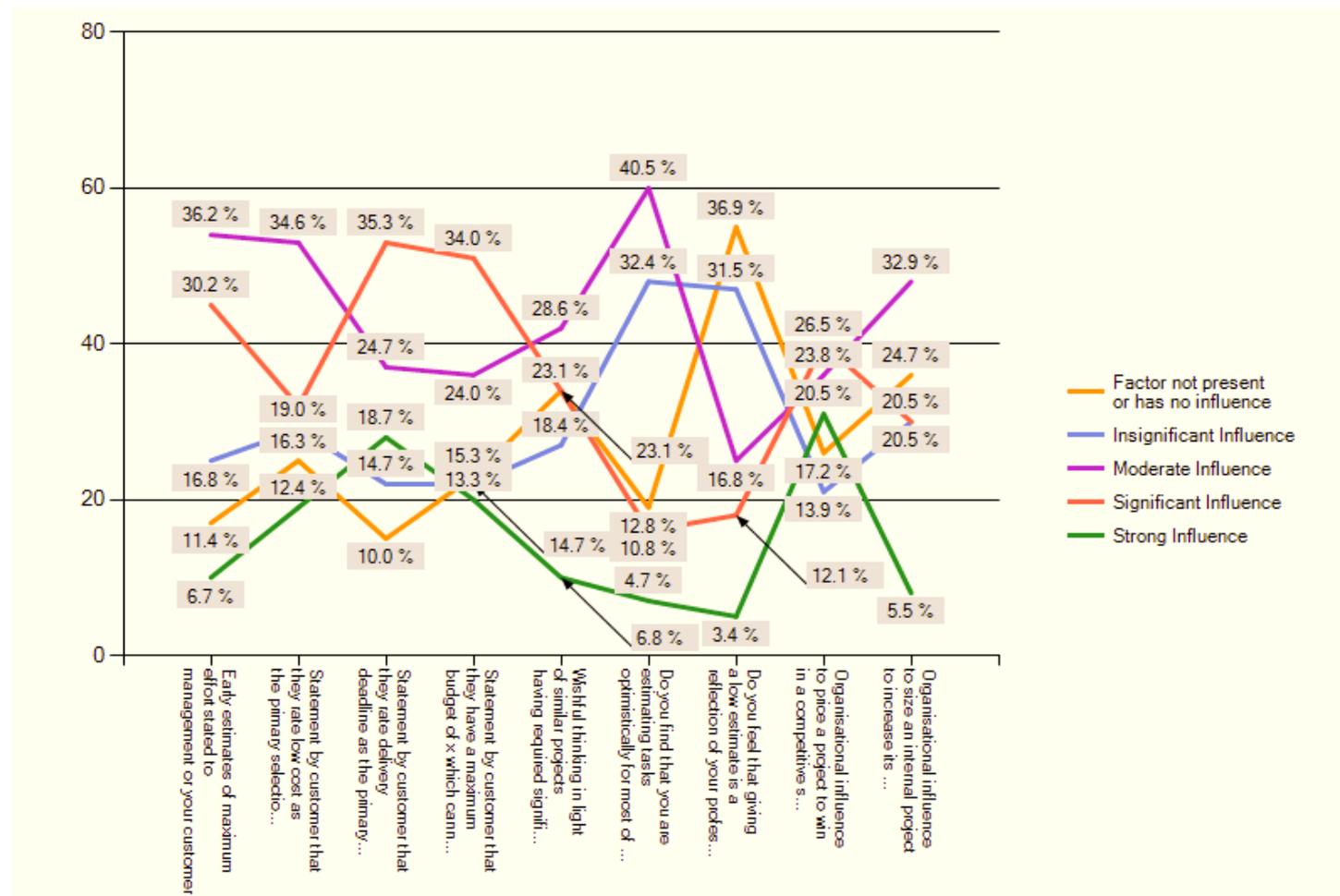
2.9 Research Question 9 Results

RQ9: Which of these factors are predominant?

Table 2-iii - Influences on Estimates – Data

Which of the following influences or behaviours have you experienced that have had an effect of limiting or resulted in you adjusting your baseline EFFORT estimates?						
Answer Options	Factor not present or has no influence	Insignificant Influence	Moderate Influence	Significant Influence	Strong Influence	Response Count
Early estimates of maximum effort stated to management or your customer	11.4% (17)	16.8% (25)	36.2% (54)	30.2% (45)	6.7% (10)	149
Statement by customer that they rate low cost as the primary selection criterion	16.3% (25)	19% (29)	34.6% (53)	20.9% (32)	12.4% (19)	153
Statement by customer that they rate delivery deadline as the primary selection criterion	10% (15)	14.7% (22)	24.7% (37)	35.3% (53)	18.7% (28)	150
Statement by customer that they have a maximum budget of x which cannot be exceeded	15.3 % (23)	14.7% (22)	24% (36)	34% (51)	13.3%(20)	150
Wishful thinking in light of similar projects having required significantly more effort than what you estimate for your project	23.1% (34)	18.4% (27)	28.6% (42)	23.1% (34)	6.8%(10)	147
Do you find that you are estimating tasks optimistically for most of your estimate?	12.8% (19)	32.4 (48)	40.5% (60)	10.8% (16)	4.7% (7)	148
Do you feel that giving a low estimate is a reflection of your professional ability to deliver to a commitment?	36.9% (55)	31.5% (47)	16.8% (25)	12.1% (18)	3.4% (5)	149
Organisational influence to price a project to win in a competitive situation	17.2% (26)	13.9% (21)	23.8% (36)	26.5% (40)	26.5% (31)	151
Organisational influence to size an internal project to increase its likelihood to be approved	24.7% (36)	20.5% (30)	32.9% (48)	20.5% (30)	5.5% (8)	146
Total Population						153

Figure 2-xxxviii - Key Influences on Estimates – Line Chart



In summary, the most predominant factors or influences on the adjustment of a baseline effort estimate (SIGNIFICANT + STRONG influence) in descending order of significance (=>33%) are:

- 1) Statement by customer that they rate delivery deadline as the primary selection criterion; 54% (n=81/150).
- 2) Organisational influence to price a project to win in a competitive situation; 53% (n=71/151).
- 3) Statement by customer that they have a maximum budget of x which cannot be exceeded; 47.3% (n=71/150).
- 4) Early estimates of maximum effort stated to management or the customer; 36.9% (n=55/149).
- 5) Statement by customer that they rate low cost as the primary selection criterion; 33.3% (n=51/153).

The least predominant factors or influences on the adjustment of a baseline effort estimate (NOT PRESENT + INSIGNIFICANT influence) in ascending order of significance (=>33%) are:

- 1) Giving a low estimate is a reflection of your professional ability to deliver to a commitment; (68.4%, n=102/149).
- 2) Estimator's belief that they estimate tasks optimistically (n=67/148) or organisational influences exist to size an internal project to increase its likelihood for approval (n=66/146) were cited by 45.2% of the respondents for these respective questions.

- 3) Estimator's wishful thinking in light of similar projects having required significantly more effort than the estimator has estimated; (41.5%, n=61/147).



“The mission of UCD is to advance knowledge, to pursue truth and to foster learning, in an atmosphere of discovery, creativity and innovation, drawing out the best in each student and contributing to the social, cultural and economic life of Ireland in the wider world.”

University College Dublin, Strategic Plan to 2014, Forming Global Minds.