# The world is skewed

Ignorance, use, misuse, misunderstandings, and how to improve uncertainty analyses in software development projects

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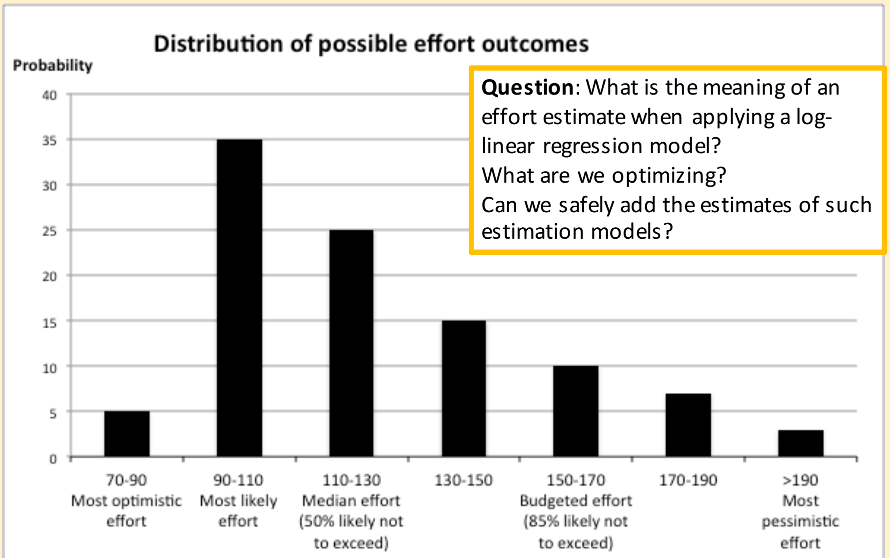
## An estimate is an estimate is an estimate?




**Question**: What is the meaning of an effort estimate when applying a log-linear regression model? What are we optimizing? Can we safely add the estimates of such estimation models?

A proper communication of what we mean with an estimate requires a probabilistic understanding!

It's fine to give a single point estimate, as long as we tell where on the distribution we are, e.g., that we communicate a p50-estimate (median estimate).

It's not precise (but common) to give a min-max interval without confidence level (and not necessarily with a confidence level either).

## Answers (log-linear effort estimation model):

- When we use ln(Effort) as the dependent variable in linear regression, we try to find the arithmetic mean of the transformed and the **geometric mean** of the non-transformed effort outcome distribution (given values of the independent variables).
  - The median value equals the geometric mean of a log-normal distribution. The median value will be the same for the normal and the log-normal distribution.
- Consequently, the meaning of an estimate in the context of a log(Effort), linear regression-based estimation model is the **median effort** (the p50-estimate).
  - To find the expected value each estimate has to be multiplied with $e^{var(error)/2}$
- The median effort has the following properties:
  - It is the value that minimizes the error of the **absolute** deviation between the estimate and the actual effort, but **not** the relative deviation.
  - Adding median effort estimates will typically **under-estimate the total effort** in situations with right-skewed distributions (which is nearly always the case).
  - Much studied under the term "the retransformation problem", but not much awareness in the SE literature ...

What about the software industry? Do they know and communicate what they mean with an effort estimate?

# A survey among software professionals

"You have just estimated the number of work-hours you think you need to develop and test four different software systems. Please select the description below that you think is closest to what you meant by your effort estimate in the previous four estimation tasks:

- *Number of work-hours I will use given that I experience almost no problems.*
- *Number of work-hours I will use given that I experience no major problems.*
- *Number of work-hours I most likely will use.*
- *Number of work-hours where it is about just as likely that I will use more as it is that I will use less effort than estimated.*
- *Number of work-hours where it is unlikely that I will use more effort than estimated.*
- *Number of work-hours based on my expert judgment/feeling of how many work-hours I will use. I find it difficult to decide about the exact meaning of the estimate.*
- *None of the above descriptions is close to what I typically mean by an effort estimate."*

| Interpretation (as claimed in hindsight) | Frequency of interpretation |
|---|---|
| Ideal effort | 37% |
| Most likely effort | 27% |
| Median effort (p50) | 5% |
| Risk averse effort | 9% |
| Don't know/gut feeling/other | 22% |

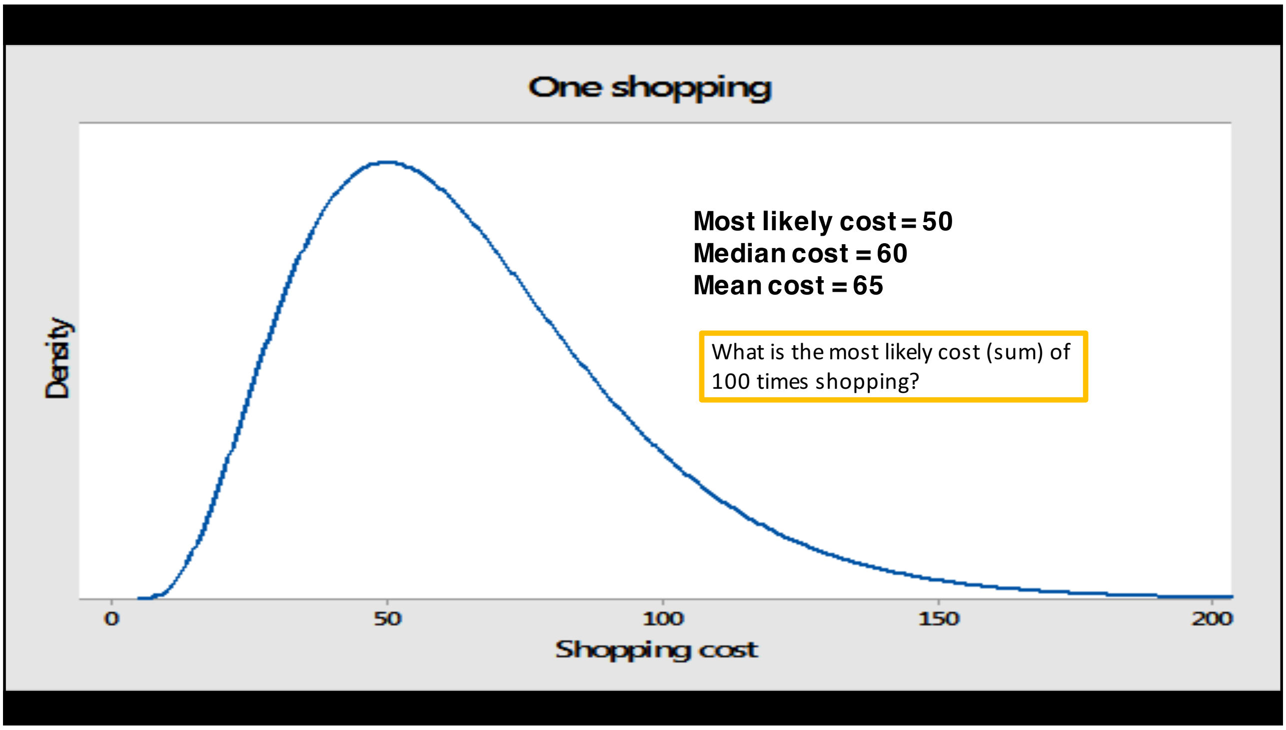
Sometimes software companies try to include uncertainty in their effort estimates.

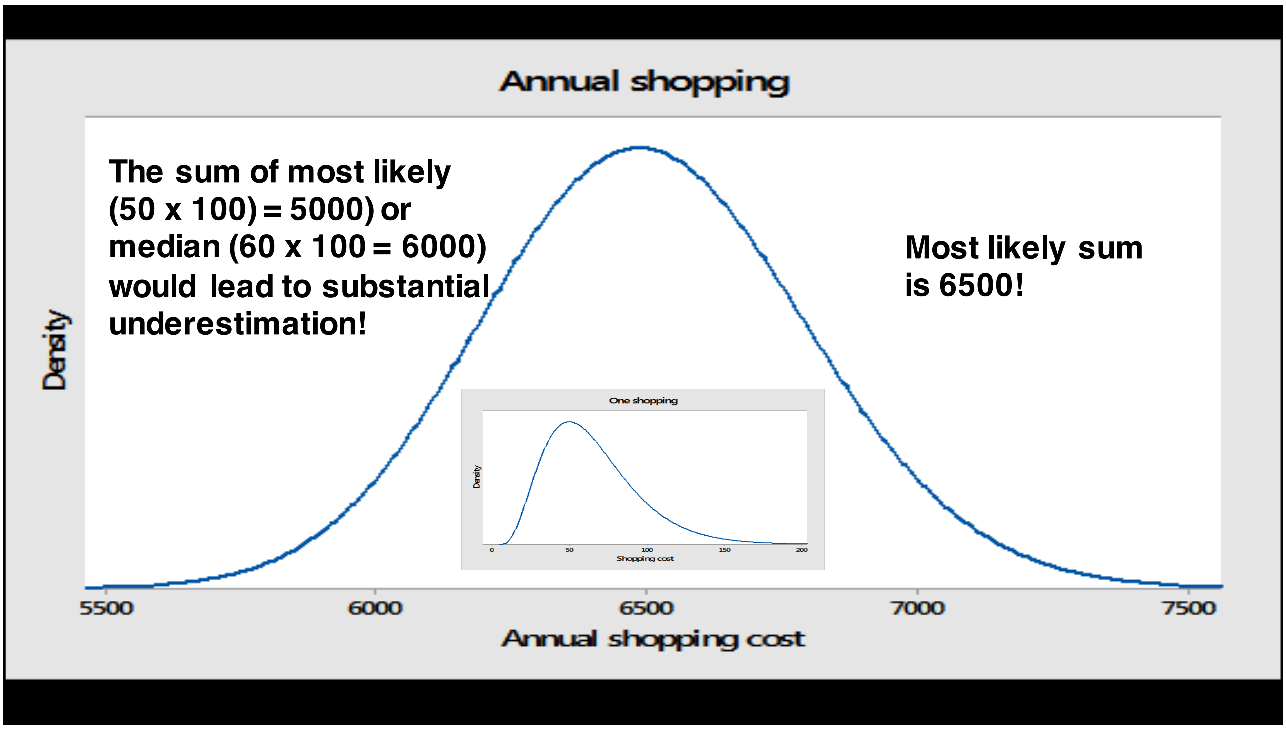
Some do it as in the table below
Exercise: Find (at least) four problems

| Activity | Minimum effort (best case, optimistic) | Estimate | Maximum effort (worst case, pessimistic) |
|---|---|---|---|
| Activity A | 15 work-hours | 20 work-hours | 25 work-hours |
| Activity B | 40 work-hours | 60 work-hours | 80 work-hours |
| Activity C | 45 work-hours | 50 work-hours | 55 work-hours |
| **SUM effort** | **100 work-hours** | **130 work-hours** | **160 work-hours** |

1. **Not communicating of what is meant** by minimum, estimate (most likely?) and maximum
2. **Too symmetric intervals.** The outcome distribution is typically right-skewed.
3. **Too narrow intervals.** Strong tendency towards too narrow effort intervals to reflect, for example, a 90% confidence inerval.
4. **Incorrect additions.** It is only the mean values that can be safely added, not the most likely, the minimum or the maximum effort. Adding most likely estimates leads to underestimation in a right-skewed world.

# A brief side-track on adding estimates in a right-skewed world






## A few, more "advanced" companies do it with asymmetric and wider intervals, and the use of "PERT". Still problematic?

| Activity | Minimum effort (p10) | Most likely (ML) effort | Maximum effort (p90) | Mean effort PERT effort = (Min+4ML+Max)/6) | Variance of effort PERT variance = (Max – Min)$^2$/36 |
|---|---|---|---|---|---|
| Activity A | 15 work-hours | 20 work-hours | 40 work-hours | 23 work-hours | 17 |
| Activity B | 50 work-hours | 60 work-hours | 100 work-hours | 65 work-hours | 69 |
| Activity C | 45 work-hours | 50 work-hours | 150 work-hours | 66 work-hours | 306 |
| **Sum** | | | Expected value = | **154 work-hours** | **392 (stdev = 20)** |
| **Uncertainty** | p85 (85% conf. not to exceed) equals ca. exp. value + stdev | | | **154 + 20 = 174 wh** | |

- The assumption of the PERT-formula is the unrealistic assumption that min=p0 and max=p100. Does not affect mean effort much, but the variance get much too small. Should divide variance (assuming p10 as min and p90 as max) by approx. $2.65^2$= 7.0 instead of 36! PERT gives much too narrow intervals.
- No support for knowing what a p10 and p90 estimate should be (No diff betwen 75%, 80%, 90% and 98% confidence intervals.)

# What to do? A long way to go …

## A simple approach leading to more realistic effort uncertainty asessments

1. Estimate the most likely effort of the new project or task.
2. Identify the ”reference class” (similarly estimation complexity of projects or tasks).
3. Recall the estimation error distribution of the reference class.
4. Use the estimation error distribution to find p10, p50 (plan), p80 (budget), p90 or whatever estimate you need.

**Example**:

- You estimate the most likely effort a new project to be 1000 work-hours and want to find the p90-estimate (which will be your maximum effort).
- In the reference class of similar projects you find that 90% of the projects had an effort overrun of 60% of less (= 10% had more than 60% overrun).
- Your p90-estimate should consequently be 1000 + 60% of 1000 = 1600 work-hours.

# We have evaluated and implemented this approach in real-world contexts

## Experiment

- 19 estimation teams of software professionals in one company.
- Estimation of the most likely effort of a project, which had just started
- Estimation of the uncertainty in terms of 90%-confidence intervals (p5 and p95).
- Two groups:
  - Group A: Uncertainty assessment ”as usual”. No support for minimum and maximum judgemnts.
  - Group B: Create the error distribution of the reference class. Provide minimum and maximum effort.
- **Results**: The teams in Group B had much more realistic views of the real uncertainty of the project.
- Two replications in real-world contexts confirm the results of improved realism.

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## So what …

- Poor communication of what is meant by effort estimates.
- Poor use of uncertainty assessment methods.
- Too narrow and symmetric effort intervals gives ”garbage in – garbage out” to unceratinty assessment methods.
- Looking back on previous estimation error is a ”simple” and effective way of improvement.
- This requires compentence and mindsets based on probabilities and distributions.
- A long way to go …