09 Models, models everywhere…

Construction projects are extremely complex systems, so in order to manage them effectively we have had to develop tools and processes to help us plan, control and assess them. And, invariably, behind each of these tools and processes lies… a model. More precisely: A decision model.

So, let us take a step back for a moment, and take just a second to look at these wonderful constructs.

Models, models everywhere

Any decision we make is based on a mental model, because, as brilliant as the human mind may be, the full complexity of the world dwarfs our understanding. So, we simplify everything: We pick what we believe to be the key aspects in a situation, and we organise them in a structure that allows us to understand the whole. In other words: we build models.

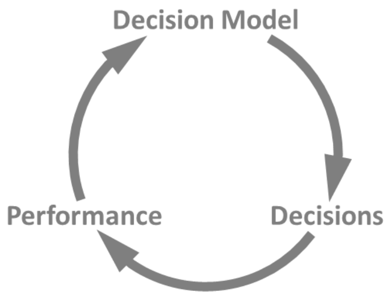

Figure 1: Decision models are based on empirical experimentation / experience.

The first decision models we used were little more than rules of thumb, and they existed only in our minds[1]. For example: Every hunter has a mental model of how to shoot an arrow at a target, and through trial and error he will refine this model and eventually be able to regularly hit the target at any (reasonable) distance, no matter the meteorological conditions. Or: Through the ages, people have had a mental model of supply and demand, knowing that they would have to pay more when items they wanted became scarce.

Mental models (such as the ones just described) are based on logic and refined by ongoing empirical experimentation. They can be quite useful – but they are still limited:

1. Mental models can only have a small number of variables, with mostly linear connections among them – any additional complexity will exceed the human brain's "computing" capabilities.[2]

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[1] For an example of the ubiquity of mental models, please see Appendix A to this article.

[2] See "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information". It is one of the most highly cited papers in psychology, published in Psychological Review in 1956 by the cognitive psychologist George A. Miller of Harvard University. Miller conjectured that there is an upper limit on our capacity to process information on simultaneously interacting elements with reliable accuracy and with validity. This limit is seven plus or minus two elements.

2. The assumptions on which mental models are based will often not be spelled out explicitly, so they can be hard to spot.
3. Mental models are not easily transferrable, and often subjective – so when we want to share our models with other people they may not work, or at least they may require a new round of "trial and error".

A developed society cannot be based on models like these. To see why, let us consider another example, only slightly more complex: Let us now imagine a merchant, who needs to equip her vessels to sail to the other end of the world, taking her products and bringing others in return. How could she possibly do this without knowing how much money she had, how much she owed, how much she had invested – in other words, how could she trade… without an accounting model? In fact, our merchant will not need just any accounting model, she will need one that she can share with her partners and teach to new generations, one that will be easily accepted, audited and understood, based on explicit assumptions, objective… in other words: She will need a model based on mathematics!

Mathematics allow us to "codify" our mental models, make them objective, explicit, and testable… and they allow us to build models to handle problems that we could not manage based solely on our own brainpower, either because they have too many variables, or because the relationship among these is too complex.

Simon's principle of "bounded rationality" summarises the last point perfectly:

> *"The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problem whose solution is required for objectively rational behaviour in the real world or even for a reasonable approximation to such objective rationality…"*[3]

Thus, mathematical models overcome the three limitations of mental models, and as our society has become more complex, we have developed more and more of these models – to handle commerce (accounting models), science (scientific theories) … and yes, also to manage construction and engineering projects!

Indeed, in the construction and engineering world we now use an almost infinite number of project decision models: We have CPM models, "line balance" models, BIM models, System Dynamics models… and many more. Some of these are complementary and fulfil different functions, but, in many instances, we have several options to accomplish the same task. So: how do we pick the model that is for us?

What makes for a "good" model?

We use models that work, models that help us to simplify reality down to a point where it becomes manageable. However, a single model will never be able to help us "manage" everything: A physical model about mechanics may help us determine the distance travelled by a moving object, but they will clearly be completely inadequate to help us to build such an object.

[3] Simon, H. (1957), "Models of Man. Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting", John Wiley & Sons (New York), pp.198,202

This fact is of course obvious to everybody, but many among us may not have thought about its broader implication: Specifically, that all models are created and developed with a purpose in mind. Jay Forrester (the father of System Dynamics) expressed this nicely in 1961:

> *"A model is sound and defendable if it accomplishes what is expected of it. This means that validity, as an abstract concept divorced from purpose, has no useful meaning."* [4]

In other words, all models are based on a series of simplifying assumptions, and we make these assumptions with an objective in mind (we want to use the model for a particular purpose.) If we make the right assumptions, the model will produce useful results… and thus fulfil its purpose.

This is what George Box meant when he said that:

"All models are wrong, but some models are useful." [5]

For example: Newton's model of gravity is wrong, as Einstein proved over a century ago when he published his "General Theory of Relativity". Today, Newton's laws are considered a gross simplification of reality, and they cannot explain at all the behaviour of physical systems under certain extreme conditions. And yet… they continue to be the basis for millions of mathematical calculations every day, because under certain conditions they still provide accurate (useful) results.

The same can be said about any of the decision models used in project management. Take the Critical Path model, for example: It clearly simplifies projects quite a bit, forcing the relationships among construction activities to fit within a very small number of pre-determined types; but it is equally clear that the tools and methods based on the Critical Path model have been instrumental in allowing us to plan and manager ever larger projects – so the usefulness of this model cannot be questioned.

Fit for purpose

Actually, Forrester was not finished where we cut him off before, he went on to say the following:

> *"What may be an excellent model for one purpose may be misleading and therefore worse than useless for another purpose."* [6]

More recently, this was reinforced by the historian Yuval Noah Harari:

> *"Scientists usually assume that no theory is 100 per cent correct. Consequently, truth is a poor test for knowledge. The real test is utility."* [7]

[4] Forrester, Jay W. (1961), "Industrial Dynamics", Productivity Press, p. 115.

[5] Box, George E. P.; Draper, Norman R. (1987), "Empirical Model-Building and Response Surfaces", John Wiley & Sons, p. 424.

[6] Forrester 1961, p. 115.

[7] Harari, Y. N. (2014), "Sapiens: A Brief History of Humankind", Signal Books - McClelland & Stewart, p. 265.

This is a perfectly obvious corollary to our previous statement that *"models are born with a purpose"* … and yet, in light of how some models are used, it bears repeating. The key to knowing when we can safely use a model is to understand the simplifying assumptions made to build it – if they apply to our situation, then the model should be useful; if they do not... then all bets are off.

However, yet again, reality is more complex: Useful mathematical models are quickly embedded into methods that deliver valuable results; then, after some time, people become so used to these methods that they no longer question the models on which they were based, and they forget the assumptions that were made in order to get these models to work in the first place. Thus, slowly, successful methods become dogmas, articles of faith, truths that are no longer questioned… and so, they almost inevitably start to be used for new purposes, purposes for which the original models were never built.

To better understand the pitfalls into which successful models can fall, let us look at two examples: System Dynamics and Building Information Modelling ('BIM'.)

System Dynamics and CPM

For well over thirty years, System Dynamics has been used to proactively manage some of the world's most complex engineering projects, especially in the defence industry. This method assesses the real causes of performance losses, and by predicting how these will continue to develop in the future, it delivers to project managers crucial information about the actual likely effectiveness of proposed policies and decisions that they may be considering.

Based on the above, we should be forgiven to believe that, clearly, System Dynamics should replace CPM as a project planning tool – but this is actually not the case at all. One of the key simplifying assumptions underlying all System Dynamics project models is that you do not need to distinguish individual work activities – in other words, that working at the higher "work phase" level is good enough to assess the dynamics of disruption. This simplifying assumption has been proven to be a very useful compromise when assessing project disruption and delay… but it clearly does not help when you are trying to deploy crews to individual activities, prioritise and track individual purchase orders, etc…

This, then, is a good example of how very different project models can still be very useful and effective… as long as each is used for its proper purpose(s).

One BIM to rule them all?

Building Information Modelling seems to be all the rage right now. BIM has upended the traditional viewpoint that *"you should model the problem, not the system"* – i.e., that you should focus on the key aspects of the problem and not clutter your model with unnecessary amounts of data that will only make it more cumbersome, and harder to validate.[8] Instead, BIM relies on using computing power and sophisticated programming to integrate different sources of detailed project data (design drawings, procurement logs, construction programmes…), carefully tracking how every piece of data is connected to all the others – and thus, how they all impact each other, and the project.

Initially BIM just integrated computer-aided drawings and construction programmes, so that the methodology could visually recreate a construction / installation process ('4D BIM'.) Since then, BIM has continued to evolve, integrating ever more data sources (e.g., cost data) to support more project decisions – and the model works,

[8] For a more detailed discussion on this topic, please refer to Appendix B.

providing managers with a new level of information that is allowing them to better plan and execute their projects.

However, BIM is now also sometimes being proposed as a disruption assessment method – and this is "a bridge too far". Yes, BIM models integrate a vast amount of project information, but in order to deal with disruption they would need to be able to explore the connections between design decisions and procurement and construction outcomes – and this is something that BIM cannot yet do (nor will it be able to do in the immediate future.) Thus, in this particular field (retrospective disruption analysis), Pickavance's 2007 statements are still valid:[9]

> *"Although it looks very convincing, in fact this animation is no more than an illustration of a narrative."*

And this is an excellent introduction to our last topic: Models evolve… and eventually they fade away.

The life of a model

As we saw earlier, models use simplifying assumptions to reduce the complexity of the real world to something that we can manage. Therefore, how much we need to simplify reality to make it manageable depends on our ability to manage complexity – in other words: It depends on technology.

And technology evolves, so that things that were not possible decades ago may become so now. System Dynamics models were at the leading edge of technology when they were first developed, back in 1958 – but it took the development of the personal computer to make them generally usable on construction projects. Similarly, full project data integration via BIM may not be practical today, but new developments in computing power, systems architecture and artificial intelligence may make it a reality soon.

But technology does not just allow for new models to rise, it also spells doom for others. Sometimes, models that were fit for purpose years ago may now no longer provide the best answer to a problem: newer technologies may evolve that require fewer simplifying assumptions, and/or make better use of available data… so the old answers become suboptimal, and new models provide better ones.

The Program Evaluation and Review Technique ('PERT') model is a good example of a mostly obsolete model: Developed in 1958 for the US Navy to support the planning and scheduling of large and complex projects, it was a CPM-like method that allowed planners to better assess the schedule risk that the project was facing.[10] In its time it was useful to assess the risk surrounding project completion dates, but its simplifying assumptions led it to systematically underestimate this risk – so when computing power became more widely available, it was replaced by CPM models that could run more accurate (and more computing-intensive) Monte Carlo analyses.

[9] Pickavance, K. (2007), "Using Advanced Forensic Animations to Resolve Complex Disruption Claims", Society of Construction Law (D87), p. 3.

[10] Simplifying it a bit, PERT was similar to CPM, but it used probabilistic activity durations (each activity had an optimistic, a pessimistic, an average and a planned duration); this data was then used statistically to estimate the probability that the project could be completed by a certain date.

In conclusion

Models are made possible by simplifying assumptions guided by an intended purpose, and they are built on mathematics and technology – only when their assumptions, purpose, mathematics and technology are all aligned, can models be truly useful to us.

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Appendix A: Mental models - the 'Kanisza Triangle'

To understand just how much our brain likes to use mental models (even without us being aware of it), let us quickly review the example of the Kanisza Triangle.

Figure A-1 below shows an image developed by Italian psychologist Gaetano Kanisza in 1955: it shows three black angles, and three black circles with a slice missing. However, when most people look at this image they see (a) a white triangle, on top of (b) another white triangle with black edges and (c) three full black circles. And, even when people are made aware of the fact that the image contains no actual triangles… they still find it difficult NOT to see them.

We see triangles that are not truly there because the brain sees a pattern that normally would constitute a couple of triangles, and assumes that what we are seeing must therefore be triangles. And, this happens automatically, we are not even aware that our brain is doing this: evolution has "trained" our brain to identify certain visual patterns under certain conditions as surfaces – and so, it "sees" them[11].

In other words: our brain uses mental models about the world we live in even when we are unaware of it doing so.

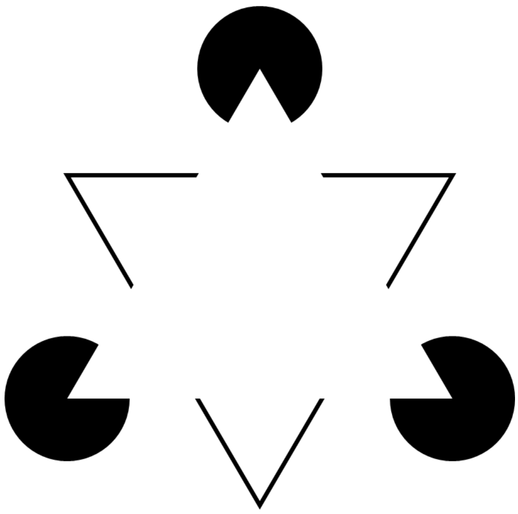

Figure A-1: The "Kanisza Triangle".

[11] Pinker, S. (1997), "How the Mind Works", W.W. Norton & Company Inc., pp. 258-259.

Appendix B: Model the problem, not the system

As Prof. Sterman at MIT states[12], we should "model the problem, not the system":

> *"Develop a model to solve a particular problem, not to model the system. A model must have a clear purpose and that purpose must be to solve the problem of concern to the [user]. Modelers must exclude all factors not relevant to the problem to ensure the project scope is feasible and the results timely. […] Focus on results."*

Turning back to George Box, he sets forth two principles to guide us in choosing which elements of the Project we should include in a model:[13]

> *"Parsimony: […] the scientist cannot obtain a "correct" [model] by excessive elaboration."*

> *"Worrying Selectively: Since all models are wrong the scientist must be alert to what is importantly wrong. It is inappropriate to be concerned about mice when there are tigers abroad."*

In other words, we should be "parsimonious" and only include elements that are likely to be relevant to our purpose, and viable based on the information available to us. And, we should "worry selectively", i.e., we should focus first on the more significant elements, and ignore the less significant ones. Including elements of reality into a model which do not contribute to the fulfilment of its purpose would not only be frivolous, but even counterproductive: such a model would become extremely complex, cumbersome and costly, and not show any corresponding improvement in the accuracy of its results.

[12] Sterman, John D. (2001), "Business Dynamics: Systems Thinking and Modeling for a Complex World", Irwin McGraw Hill, pp. 79-80.

[13] Box 1987.