Models and Modelling: A Case Study



(Magritte, 1929)

# Dell’s Channel Transformation: Leveraging Operations Research to Unleash Potential Across the Value Chain

## Introduction

The purpose of this essay is to reflect on aspects of models, as used in the field of Management Science, and on the modelling process itself, with particular reference to the industrial case study (Martin et al., 2014) that appears in the title above. The article chosen was published in the Operations Research journal *Interfaces* in January 2014 and was a finalist in the 2103 Franz Edelman Awards competition, an annual contest designed to highlight exceptional examples of OR/MS practice.

At the time of publication, Dell Inc. was the world’s third largest personal computer vendor in terms of market share (iCharts, 2014). In their paper, the authors describe three main “solutions” [models] that were developed in response to Dell’s transition from a predominantly configure-to-order (CTO) sales approach to a supply model that emphasised delivering fixed hardware configurations (FHCs), as part of a response to evolving customer attitudes to purchasing technology, including personal computers. For the purpose of this essay, the focus will be on just one of these three models, namely that which the authors refer to as the “Online Conversion Rate Accelerator” (“OCRA”).

## Online Conversion Rate Accelerator

The Online Conversion Accelerator is, in essence, a model of the various components that appear on a sales web page on Dell’s website, along with certain technical and business constraints, formulated as a non-linear, mixed-integer program. More specifically, the objective function is to maximise the “conversion rate” (that is, the proportion of customers browsing the web page who then progress to placing an order) which is modelled as the sum of the “main effects” and “interaction effects” relating to a specified set of permissible webpage components, such as “buttons” and “deal banners”, with each component represented by a binary variable and an associated coefficient. The model constraints include a specified minimum and maximum number of page components; merchandising restrictions on certain combinations of FHCs being displayed on the same web page; a restricted permissible set of combinations of page components (based on a sub-model, to be discussed later in this essay); upper and lower bounds for product prices; limitations on permutations of website navigation elements; and an upper limit on the time taken for a web page to load, given its constituent parts.

The model described above is in fact the final link in a chain of three models, with the inputs to the above model being derived from another that utilises multivariate testing and A/B testing to generate a set of distinctive permutations of web page components. The authors refer to each of these permutations as a “recipe”. Extending the authors’ analogy, the ingredients for these recipes stem, in turn, from the initial model in the sequence, that was designed to generate a complete inventory of the individual elements of web page design that have a bearing on the conversion rate. The reported methods used to isolate these components include some that are widely used and recognised, such as key driver analysis and text mining, as well as borrowing from more specialised techniques from the literature, including behavioural analysis (Padmanabhan and Tuzhilin, 2003), website-specific usability testing (Hinchliffe and Mummery, 2008) and pathing analysis, an approach that analyses user/website interaction based on website metrics data (Weischedel and Huizingh, 2006).

The stated purpose of the OCRA model, as defined by the model’s objective function, was to maximise the online customer conversion rate. Additionally, the authors appear to have linked the model to two further outcome measures, namely online customer satisfaction and “margin improvement”, although the motivation and basis for doing so is unexplained in the text. It appears that the degree of customer satisfaction may have been assessed by means of a questionnaire: the paper states that “…the overall satisfaction of online FHC customers improved from 27 to 45 percent as a result of the improved purchase path”. It is difficult to draw any firm conclusions from this assertion. Presumably it does not mean that, on average, individual customers went from being “27% satisfied” to “45% satisfied”, as it is difficult to conceive such a measure being valid. More probably, the implication is that the proportion of respondents indicating a certain, subjective, qualitative level of satisfaction with the purchasing process increased from 27% to 45% [one hopes that the measure was not simply a binary choice between “satisfied” and “unsatisfied”!]. Even so, the latter portion of the statement (“as a result of the improved purchase path”) lacks justification, and one might speculate that other, confounding variables, such as price, which is well documented as exerting a significant influence over customer satisfaction in the online retail environment (Jiang and Rosenbloom, 2005) may be at play here[[1]](#footnote-1). Similarly, the claim that “a margin improvement of $33.5 million” was as a direct result of “implementing various changes recommended by these OCRA processes” is somewhat tenuous and left uncorroborated. With regards to the objective function of the model, the online customer conversion rate, the authors report that “various merchandising changes made as part of OCRA helped increase the online FHC sales mix from seven percent in 2010 to 38 [sic] percent in 2012”. There are a number of issues with this statement. To begin with, the proportion of sales that are FHCs is clearly not the same as the stated objective, that is the proportion of visitors to the sales page who subsequently go on to complete a purchase. Further, as with the two previous claims, in the absence of evidence for a causal relationship, the predicate of the statement is something of a *non sequitur*: one might reasonably speculate that an increase in FHCs as a percentage of all sales could be anticipated simply on the basis of Dell switching to a FHC sales model, optimised or not, in preference to a CTO sales model.

The Online Conversion Rate Accelerator model was developed with a view to informing senior executives within Dell, specifically Dell’s “online business managers” (OBMs). Interestingly, whilst regional variations of the model were generated (on the basis of location-specific constraints), the models were implemented centrally by a “global project management team”. There appears to have been an initial degree of reluctance to accept and adopt the model, apparently owing to the fact that some of the model’s conclusions were contrary to existing beliefs: the authors describe the example of an unanticipated, inverse association between the number of deal banners on a web page and the associated conversion rate. This preliminary resistance dissipated, seemingly on account of the results of successive, incremental “pilots” of the model, leading progressively to managerial acceptance, subsequent full-scale roll-out and finally to adoption in preference to the prior approach of page design based on expert knowledge and acumen.

# What constitutes a “good” (Management Science) model, and what are the characteristics of a good modelling process?

## What constitutes a “good” model?

The use of the word “model” in English dates back to the latter half of the 16th century, according to at least one online source (Etymonline.com, 2014):

[model (n.)](http://www.etymonline.com/index.php?term=model&allowed_in_frame=0)

1570s, "likeness made to scale; architect's set of designs," from Middle French modelle (16c., Modern French modèle), from Italian modello "a model, mold," from Vulgar Latin \*modellus, from Latin modulus "a small measure, standard,"

This primordial definition of a model may suffice for certain instances of physical models, but lacks the qualities necessary to capture the sophisticated essence of what we mean by a model in our specified context. The question as to what constitutes a good Management Science model is perhaps best answered by separating the question into two constituent parts as follows. First, the shorter (but not necessarily simpler) question, “What is a model?”, and second “How does one define ‘good’ in this context?” For each of these questions, it is also apropos to enquire, “According to whom?” and so appropriate references shall be provided to support any claims.

In constructing a response to the first question, “What is a model?”, both Williams (Williams, 2008) and Wahlström (Wahlström, 1994) utilise a definition taken from the Collins English Dictionary (1986) as a starting point:

“a simplified representation or description of a system or complex entity, especially one designed to facilitate calculations and predictions”

[Fast forward to the present day, and that definition remains unchanged (Collinsdictionary.com, 2014).] This, surely, represents an improved definition from our chosen perspective, providing a description that is more detailed and that uses a vocabulary that seems more applicable to the realm of conceptual, rather than physical, models. The definition introduces the concept of the distinction between a detailed and intricate actuality on the one hand, and a less complicated portrayal of that reality on the other, before alluding to the notion of a model having a purpose. From here, the authors diverge in their approach to answering the question of what constitutes a model. Wahlström progresses to effectively describe a “model of a model” and whilst such an approach has merit, it lacks concision and leaves us yet to clear the first hurdle in our pursuit of a definition that is, at once, sufficiently succinct and yet satisfactorily comprehensive (a duality that applies, as we shall see, to the very models that we seek to describe). Conversely, Williams continues with what might itself be considered a small-scale modelling exercise: using the dictionary definition as a prototype for the finished product; describing a sequence of iterations in which he reflects on elements of the growing definition; refining each element in turn whilst also adding components deemed necessary to encapsulate the essence of a Management Science model, before arriving at the endpoint – a “model” defined in a single sentence, thus:

“A model represents or describes perceptions of a real situation, simplified, using a formal, theoretically based language of concepts and their relationships (that enables manipulation of these entities), in order to facilitate management, control, understanding or some other manipulation of that situation.”

It is instructive to step through the elements of this definition, examining how each concept accords with the more widely held views portrayed in the literature before supplementing this description of a model with some further desirable attributes.

### A model is a representation of reality, not reality itself

Of all of the features of a model to be explored within this essay, this first is perhaps the most crucial to acknowledge, for the concept of distinction from reality is essentially a *sine qua non* for the type of models under consideration here. A model can never equate, in scale, detail, or complexity to that which it purports to represent. In the event that such an accomplishment were possible, then there would be no advantage to be gained from studying the model as opposed to the reality itself. Korzybski argues, however, that such a feat is infeasible in any case: referring to “models” as “maps”, he states that “if the map could be ideally correct, it would include, in a reduced scale, the map of the map; the map of the map of the map; and so on, endlessly…” (Korzybski, 1931) and, in what has become a familiar maxim, cautions us to be ever mindful that “the map is not the territory”. It is worth noting at this point that the proposition that a model is a representation of reality does not imply the reverse proposition that a representation of reality is a model. One might formulate a representation of reality within the mind, but this mental construct does not become a model until it is externalised and explicitly stated, according to Pidd (Pidd, 1999). In Pidd’s words, “This means that the model can be examined, can be challenged, and can be written in a logical language, such as that of mathematics or computer programming”.

### A model reflects one of many possible interpretations of a real scenario

It is difficult to argue the case for a universal reality from a human perspective, as each individual carries with them their own set of values, beliefs and biases formed by the complex interaction of his or her own distinct experiential history with a unique amalgam of personal characteristics including age, race, gender, culture, religion, etc. It is necessary for the practitioner to acknowledge that the data that may be used to construct a model, as well as any depiction of the environment in which the model is to be used, will necessarily have been passed through such perceptual filters. The skilful analyst will take steps to ensure that, as far as possible, any prejudices incorporated into the model are those of the intended users of the model. Little makes this point in his description of a model as a “decision calculus” (Little, 2004), advising that “if we want a manager to use a model, we should make it his, an extension of his ability to think about and analyse his operation” and that this is best achieved by ensuring that the inputs of the model “represent the operation as the manager sees it”. One should also acknowledge that the outputs of a model are processed through similar perceptual filters. Models do not make decisions: managers do. Thus, considerable importance must be placed on the interpretation of a model’s output and not just the output itself. In the event that guidance is sought from the analyst on the output of a model, he or she would be wise to talk in terms of expectation, perhaps based on experience and with reference to the model assumptions, but always mindful of the advice of Barabba, in what has been termed Barabba’s Law: “Never say the model says” (Barabba, 1994).

### A model should strive for simplicity as well as simplification

The point has already been made above that a model that encapsulated reality in its entirety would confer no advantage to the user. And yet there seems to be an almost instinctive desire to add detail and complexity to models, perhaps for fear of omitting some critical component. Certainly, such a propensity has been observed and remarked upon in the literature, with Salt describing the tendency as “bagatellomania” (Salt, 2008) driven by “trifle-worship” (a mistaken belief that a more detailed model is a better model). Salt acknowledges that the appropriate level of complexity may be difficult to judge, but suggests that it is easier to add further detail if required than to remove it once incorporated. Other authors offer some guidance as to where to draw the line. Wahlström, for instance, proposes that “a model should be refined enough not to be trivial, but simple enough to bring forward only the essential characteristics of the real system” (Wahlström, 1994), with Little echoing the sentiment thus: “Important phenomena should be put in the model and unimportant ones left out” (Little, 2004). Others, such as Vaandrager, reference the *lex parsimoniae* espoused by William of Ockham in the 14th century, that in choosing between a number of apparently equally valid hypotheses, preference should be given to that which relies on the fewest assumptions. This principle of parsimony, often referred to as “Occam’s razor”, has been modified and adopted in many fields of study. Vaandrager’s take on it, with reference to modelling is as follows: “A good model is simple (but not too simple). Occam’s razor is a principle particularly relevant to modelling: among models with roughly equal predictive power, the simplest one is the most desirable” (Vaandrager, 2014). In determining what is important, it may be instructive to consider carefully the model’s purpose, a point made by Pidd who, in acknowledging the incompleteness of a model, says “the representation is partial, and the partiality is governed by people’s intended use of the model” (Pidd, 1999).

A concept that, to an extent, must compete with a model’s simplicity is that of “completeness”. It is important here not to conflate completeness with complexity. Complexity may be tempting, but is generally to be deprecated, whilst completeness may be overlooked, particularly with respect to more qualitative components of a model, as Little points out: “An important aid to completeness is the incorporation of subjective judgements” (Little, 2004).

### A model should be well framed

Dewey said that “a problem well put is half solved” (Dewey, 1938), although Einstein before him seems to place an even greater proportional importance on problem structuring, having reputedly declared, “If I had an hour to solve a problem, I’d spend 55 minutes thinking about the problem and 5 minutes thinking about solutions”. He is also credited with expressing the same sentiment with these words: “The formulation of the problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill”. Pidd highlights one of the benefits of appropriate framing by intimating that “structuring a problem properly is a key to forming a lower bound on the optimal simplicity of a formal model”. The structuring, or framing, of the problem to be modelled also incorporates Williams’ inducement to make use of “formal, theoretically based languages”. Often the problem will be expressed in terms of recognised approaches or algorithms, such as the linear program model in the case study of interest here. Frequently too, models will rely upon or build on previously published work: this has the potential benefit of permitting a sense of familiarity with the workings of the model for those who wish to study it. Morris refers to this anchor as “relatedness” and asks “How many previously known theorems or results does the model bring to bear upon the problem?” (Morris, 1967).

### A model should have a (specific) purpose

Vaandrager makes the point that “a good model has a clearly specified object of modelling” as well as a “clearly specified purpose” and expresses the view that it is preferable to build several purpose-specific models than a single multi-purpose one (Vaandrager, 2014), although this is at variance with Pidd’s contention that a clearly identified object of the model need not necessarily be accompanied by universal agreement on the implementation of the model (Pidd, 1999). Willemain appears to favour Vaandrager’s perspective, in suggesting the creation of “a unique model for each problem” (Willemain, 1994). The ideas of simplification and specificity are fused in what Phillips describes as a “requisite model”, which he defines as “a model whose form and content are sufficient to solve a particular problem” (Phillips, 1984). Landry *et al* (Landry, Banville and Oral, 1996) and Wahlström (Wahlström, 1994) define the purpose of models generally, in terms of knowledge creation, thought promotion, increased understanding and decision support leading to useful action and favourable outcomes, with Wahlström emphasising the facilitative role of models: “Models can also be used for *training* of human decision makers to make better decisions”.

### A model should be useful and usable

The usability of a model relates largely to its inputs, whilst the usefulness of a model is more a function of its outputs. In terms of usefulness, output that leads to erroneous conclusions are clearly undesirable, but so too is output that is too closely aligned to that which is anticipated, since no fresh insight is gained. This has been observed by Wahlström who concludes that “a good model should therefore always generate surprises. However, if the results deviate too much from what is expected, then these results tend not to be believed, regardless of their validity. A model, when it is as best, should therefore generate only mild surprises which can be believed or at least supported with common sense reasoning from the model assumptions” (Wahlström, 1994). In his discussion of “requisite models”, Phillips cautions that the usefulness of a model is tied inexorably to the conditions that led to its creation, with particular regard to the users of the model and their subjective perceptions. Even without a change of scenario, or environment, the usefulness of a model may be substantially depleted under a change of ownership and *vice versa*.

Little makes the point that, for a model to be ‘usable’ (in contradistinction to ‘useful’) the user interface must be sufficiently intuitive with respect to both input and output functions (Little, 2004). Landry *et al* expand on this by explicitly noting that the model should seek to address the trade-off between being adequately intricate to address the given problem and falling within the “cognitive capacity” of the users of the model (Landry, Banville and Oral, 1996). Usability may also be affected by factors that are easy to overlook, such as the model’s financial and resource implications (Gass, 1987).

### A model should be flexible

A model may be considered flexible by virtue of adaptability or extensibility. The division between these two properties is somewhat blurred, but adaptability connotes evolution of capability with retention of original objective, a feature advocated by Little in suggesting that a “model should be capable of being updated as new information becomes available. This is especially true of the parameters but to some extent of structure too” (Little, 2004). Extensability, conversely, implies a branching of purpose obtained either by progressive growth of the original model, or preferably by seeding a generation of related models designed for application to a class of similar (yet unique) problems (Vaandrager, 2014).

### A model should be robust and produce valid results

The robustness and validity of a model could be considered another pair of input/output features respectively. A robust model is one that is capable of tolerating deviations from the underlying assumptions to some satisfactory degree, according to Morris (Morris, 1967). This technical definition parallels the more pragmatic description offered by Little: “Robust. Here I mean that a user should find it difficult to make the model give bad answers” (Little, 2004).

Validation follows verification; verification being a quality-control procedure to ensure that the model has been deployed and implemented as specified in the formulation, whilst validation ensures that the output of the model is a plausible portrayal of the system of regard, based on input data distinct from that used to construct the model in the first place (Wahlström, 1994). Landry *et al* remind us that such validity is dependent on the subjective appraisal of the model’s output by what he terms the “strategic stakeholders”; those who are most likely to engage with the model and have ultimate control of the decision process (Landry, Banville and Oral, 1996).

### A model should be transparent

Salt warns against concealing the underlying workings of a model, as this prevents the model users from sharing the modeller’s understanding of how inputs are transformed to outputs, what he calls “the black box mistake” (Salt, 2008). As Pidd points out, hidden mechanisms may engender distrust of the model (and/or modeller) (Pidd, 1999) on the part of the client, potentially rendering the model useless.

### Putting it all together

Any attempt to rank the above properties of a “good model” will always be subjective, but Willemain did just that in 1994, asking “twelve selected expert modelers” to list the “qualities of an effective model” in order of importance (Willemain, 1994). The summary of responses was as follows: “1) validity, 2) usability, 3) value to the client, 4) feasibility, and 5) aptness for client’s problem”.

Finally, in contemplating the desirable features of a model, Vaandrager (Vaandrager, 2014) offers a summary that does not deserve to be paraphrased and is therefore reproduced here, unaltered:

“Often, the criteria are hard to meet and typically several of them are conflicting. In practice, a good model is often one which constitutes the best possible compromise, given the current state-of-the-art of tools for modelling and analysis. But a truly beautiful model meets all the criteria!”

## What constitutes a good modelling exercise?

1. “One of the first things taught in introductory statistics textbooks is that correlation is not causation. It is also one of the first things forgotten.” (Sowell, 1995) [↑](#footnote-ref-1)