Living Business Models for Strategic Management Accounting

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This full paper is summarised in the LinkedIn 'Pulse' article at sdl.re/LIPSMA.

Contributing to the strategy process in businesses and other organisations is a central role for management accounting professionals. However, fulfilling this responsibility demands capabilities and methods that go beyond the purely financial techniques that dominate even strategic management accounting practice (SMA). True SMA requires the same rigorous, quantified appraisal of how an organisation's customers, human, physical and intangible factors are changing that has traditionally been done for the financials. And that appraisal must also recognise the holistic and systemic nature of the enterprise.

This article argues that simulation of Living Business Models (LBMs) is the only adequate solution to this challenge. An LBM or dynamic model connects all aspects of an organisation's strategy, linking the financials back to how customers, products, capacity and staff interact in a working system to drive those financial results – precisely the "joined up management" everyone claims to want. Furthermore, an LBM offers a continuous picture of the trajectory-through-time of all business elements and a projection of how the entire enterprise may develop and perform into the future, enabling pro-active management of the strategy.

The process of building a dynamic model is both rigorous and practical – easier and faster, in fact, than attempting time-based business modelling with spreadsheets. Attachment 1 reviews how LBMs might exploit and complement existing techniques used in SMA, and the article concludes by proposing that the building of working, quantified business simulations should be a core capability of all management accountants.

The Management Accounting profession has long contributed to the strategic management process in businesses and other organisations. Both the Chartered Institute of Management Accounting (CIMA) and the Association of Chartered Certified Accountants (ACCA) see this as a critical role for accounting professionals. CIMA defines Strategic Management Accounting (SMA) as … '*the provision and analysis of management accounting data about a business and its competitors, for use in developing and monitoring business strategy*'.

However, the CIMA report "*Management accounting in support of the strategic management process*", (CIMA, 2015) finds there has been little agreement among academics and professionals on the definition of SMA and the techniques that might be deployed in its practice.

ACCA's extensive online learning resource includes as part of its Performance Management topic a module on SMA which summarises established strategic planning methods and frameworks. However, those methods and frameworks (*which mostly come from the academic Strategic Management field*) are largely descriptive and qualitative and offer no means for computing the actual financial performance of any organisation to which they are applied. They are also almost entirely static in nature – any assessment of an organisation's strategy made with those frameworks will likely return the same conclusions for many years, in some cases for many decades. They thus offer no basis for explaining how the enterprise and its performance have changed from period to period, nor for estimating how that enterprise and its performance might develop in future periods.

It appears that in the German-speaking world and much of former E Europe, the 'Controlling' profession has always had a much more strategic role than just reporting and analysis (See the [International Group of Controlling]) Controllers are often the internal strategic consultants supporting the CEO and Exec board with authority to initiate studies and projects they believe to be important (see the IGC's [Controller Competence Model]).

Connecting Strategic Management Accounting to Strategy and Business Models

Strategy. Since the purpose of SMA is to help "develop and monitor business strategy", it will help to clarify some of the activities and terms to which SMA must connect. First, an adequate definition of "strategy" for the current purpose is:

"*… how an organisation goes about achieving its longer-term aims*"

… where "how" encompasses the whole range of activities and policies chosen by management from time to time. "Activities" include anything done to develop or operate the enterprise, and "policies" are the routines or guidelines used to inform decisions. Those longer-term aims may, of course, be revised as circumstances change, so the activities and policies will also be changed.

Longer-term aims are typically few in number and may include both financial measures such as annual profit (appropriately defined) and non-financial indicators such as growth of customer numbers.

Non-business cases. Public services, voluntary and other non-business organisations also have strategies and also rely on analysis and interpretation of data provided by management accountants, so SMA should address their needs also.

Business models. Progress towards those few high-level, longer-term aims requires a well-functioning business model (or operating model in non-business cases). That "model" consists of ***tangible*** factors – such as customers, products, people, capacity and cash – interacting with each other both to develop the enterprise itself and to deliver the required performance outputs. Outputs may include, but not be limited to, longer-term aims and may cover both financial or other forms of output – provision of customer service as well as cash flow, for example. The organisation will only function well, however, if certain ***intangibles*** are sustained, such as staff skills, market reputation, quality and knowledge.

SMA must, therefore, reflect a full understanding of that business model or operating model – both its elements and the way in which those elements interact to deliver performance. Unfortunately, most definitions, frameworks and methods for developing "business models" are, like other strategy tools, descriptive, qualitative and static, so provide no means for SMA to employ data to help develop and monitor the strategy.

The ***living*** business models this paper explains and demonstrates are in a quite different league from common business-model approaches, and do not suffer the same limitations.

Beyond financials. While management accountants clearly start from a focus on financials, most already expect to report also on some non-financials, such as service quality or staff turnover. But since the business model clearly consists of many critical factors other than cash, a complete SMA service must provide and analyse data on ***the full range of non-financial factors*** that make up the organisation.

External environment. CIMA's SMA definition already recognises that progress towards longer-term aims is not entirely in the hands of the organisation itself – competition also impacts that progress.

But, as the ACCA's module on SMA explains, many other external factors impact an organisation's growth and performance. SMA, then, must not only report on such issues, but also assess how they impact on the organisation's ***quantified*** results; for example, the impact of economic growth on customer numbers, sales and revenue; the future availability of required staff; the efficiency or transformational impacts of new technology.

Functional plans. The need for strategic plans is not limited to the enterprise as a whole, but also arises for every significant department of the business – HR, information-systems, marketing & sales, and so on. Naturally those plans must be consistent with the overall plan but will go into more detail on key issues for that function – for example, staff skills and experience, IS capacity and reliability, customer segmentation.

One-off issues and initiatives. The continuing, long-term plans of the enterprise and its key functions do not encompass everything of strategic importance to the organisation. One-off issues will also require attention, such as fixing a service quality problem or fighting off a competitive attack. There can also be substantial initiatives that need SMA support, such as entering a new market, making an acquisition or other strategic investment decisions.

Continual implementation. Strategy may often be seen (*incorrectly*) as a "develop and monitor" process, with development happening through some strategic planning activity, after which the organisation gets on with making the strategy happen and monitoring progress as it goes. In reality, strategic management is a ***continuous*** process, in which managerial policies and choices constantly evolve, informed by insightful ***interpretation*** of data about how the organisation is functioning and performing. If SMA is to help achieve longer-term aims, then, it must continually inform implementation of the strategy – annual or quarterly reporting supplemented by one-off investigations of specific issues is not adequate.

Extended definition of Strategic Management Accounting

The considerations above imply that CIMA's definition of SMA should be extended, as follows:

> *'SMA is the **continual** provision, analysis **and interpretation** of management accounting **and non-financial** data about **an organisation,** its competitors **and operating environment**, for use in developing, monitoring, **implementing and revising the organisation's** overall strategy and those of its **key functional units**, and for evaluating and managing **significant issues and initiatives**.'*

These adjustments impose considerable requirements on the practice of SMA:

1. SMA must provide, analyse and interpret ***all*** factors involved in the organisation's business model, not just financials, and it must do so fully – it must address everything strategically relevant about customer development, staffing changes, service quality, production operations and so on.
2. That data, analysis and interpretation must be done for those factors ***in their own terms*** – financial proxies, such as revenue-growth rates or staff-cost ratios are totally inadequate. It is ***customers*** we win and lose, ***people*** we hire, promote and lose, not dollars or ratios.
3. SMA must analyse and interpret how those factors ***interact*** with each other to drive the changes taking place to the organisation's performance and to its own development.
4. SMA must analyse and interpret how ***external*** factors interact with the organisation to influence its performance.
5. SMA must do all this ***quantitatively*** and ***continually*** – it should provide a total understanding, at all times, of the functioning and performance of the entire enterprise.

6. It must provide estimates of mid- to long-term ***futures*** – how the organisation will likely develop and perform under a plausible range of scenarios and strategies.

Foundations for truly Strategic Management Accounting

These requirements for SMA may seem so extreme as to be entirely out of reach, but there ***is*** a path to fulfilling them. That path is not technically complex, it builds on well-understood principles, and it requires no special analytical skills. The path involves:

- defining non-financial factors in a rigorous, quantifiable and reliable manner ("*reliable*" *meaning that any two skilled professionals would measure the same things in the same way*)
- adding similarly rigorous definitions for all relevant external factors
- specifying the arithmetical relationships by which those factors interact with each other to cause the system itself to change over time
- formulating how those same factors drive performance outcomes, including financial results, and how they drive changes to the system itself
- assembling all those factors and relationships into a working, quantified model that replicates the organisation's development and operating performance – a simulation that accurately mimics the observed behaviour of the entire system and projects that behaviour into the future.

Developing such simulations has long been possible using the "***system dynamics***" method but is now sufficiently practical to make true SMA achievable for any competent professional. The following paragraphs summarise how that method works and how it can lead to the LBMs we need.

"Asset stocks" *(or simply "stocks" or business "resources")*. For a working model to replicate the behaviour of a real-world organisation, all factors that make up that organisation need to be specified in a rigorous and quantifiable manner that does not rely on judgement or interpretation. Fortunately, the means for doing this already exists, because all such factors are "asset stocks", or simply "Stocks". In summary, an asset stock is a collection, group, population, mass or volume of materials or entities that accumulates or depletes over time. (*See Attachment 2 for a full explanation of asset stocks.*)

Virtually all organisations feature a small standard set of strategically relevant resource stocks:

- ***Customers***
- The ***products or services*** provided
- ***Staff***
- Physical ***capacity*** units (*in service cases, staff may form that capacity*)
- ***Cash*** and debt

(*These resources need not all be owned and controlled by the enterprise - some may be accessed through licenses, contracts, out-sourcing or other means*)

Other common strategic stocks include ***intermediaries*** (our direct customers, and maybe *their* customers, through which goods pass before reaching the final user) and ***points-of-presence*** (e.g. retailers' stores, drink-dispense-machines, airlines' destinations). Sector-specific strategic stocks include *reserves* for natural-resource producers, *land* for agricultural businesses and *projects* for advisory firms and construction businesses.

There are also some other, less-strategic stocks, such as *inventory, outstanding orders* and *debtors* (both the customers who have not paid, as well as the financial value of their debts).

Non-business organisations mostly feature the same limited set of strategic asset stocks – some population driving demand (such as criminals who drive the crime-rate); a range of services offered; staff and physical assets needed to develop and deliver those services. Voluntary groups may in addition feature a resource-stock of '*donors*'.

External factors also include asset stocks – the population of potential customers that neither we nor competitors have yet captured, the stream of emerging students from whom we seek to hire, the customers of competitors, and so on. However, not all external influences consist of stocks – weather, inflation or regulation for example.

It may be helpful to avoid the implied technicality of the term "asset stocks" and the ambiguity of just "stocks", by choosing instead the managerial term "resources".

> ***An organisation's resources are all types of items that are important for the organisation to function, and that must be acquired, developed and sustained over time. It may own or control those items*** (e.g. production equipment) ***or have reasonably reliable continuing access to them*** (e.g. staff and customers).

Stock-accumulation – the 1-to-1 match with the core accounting principle. The defining characteristic of any asset stock is that its quantity can only be changed by the rate at which new materials or entities are flowing in, and/or the rate at which existing materials or entities are being lost – its flow-rates, or simply "Flows". Simple examples include customers won or lost, staff hired, fired or lost, products launched or dropped, and capacity added or retired.

> ***The accumulation and depletion over time of every asset-stock operates in precisely the same way as the accumulation and depletion of cash and all financial balances.***

This means that management accountants can use precisely the same discipline to "account for" changes to customers, staff, products, capacity and so on that they have always used to track movements of cash and value. It is quite straightforward, for example, to produce a "customer-flow statement" or "staff-flow statement" for any period.

Complications with non-cash Stocks. Some characteristics of non-cash stocks add complications that do not apply to cash:

- While cash is entirely uniform, other stocks ***vary in quality*** – often on more than one indicator. Customers vary in their purchase-rate and service-demand, staff have varying skills and salary costs, products differ in their appeal to customers, and capacity units vary in their output capacity, reliability and operating cost. Such qualities can be handled by attaching an "***attribute***" to the stock, which both moves with the stock (*we hire and lose people of varying skill levels*) and changes independently of the stock (*we train existing staff*).
- Each resource stock may be divided between different ***segments or groups*** – customers of different sizes or in different regions, staff in different functions, product-groups, capacity of different types. This simply requires use of ***copies*** of the stock for all such groups or segments.
- Items may ***move*** from state to state – staff move from trainee to junior to senior levels, products move through product development stages, and so on. This is handled with ***chains*** of stocks, all of which contain the same type of entity, connected by flow-rates that move entities from one state to the next.

Stocks drive performance. Customers drive sales and revenue, staff drive work-capacity and labour costs, capacity drives maximum output or throughput and some operating costs. Many such relationships are precisely arithmetical (*sales/month = Customers * sales/month per customer*).

Others can be quantified with estimations (*service quality* varies with the ratio between *workload* and *service-capacity* in person-hours per period).

These relationships require a different mind-set than is commonly adopted. While it may be arithmetically true, for example, that *sales* = *market size* * *market share*, this is not ***causally*** accurate – customers drive sales. Likewise, it may be arithmetically true that *labour cost* = *revenue* * *% labour cost*, but labour cost is actually driven by the number of people employed and their average cost of employment, regardless of what revenue rate happens to be occurring.

Managerial ***decisions*** also drive performance – changing prices or spending-rates directly cause changes to revenue and costs, for example. ***External factors*** also directly drive current performance, as when bad weather slows consumers' purchase rates, or a competitor price move changes the fraction of customers' purchases that we win.

Note that this "stocks-drive-performance" principle applies to both financial *and* non-financial outcomes – service quality reflects the balance between service demand from customers and the service capacity provided by service staff.

Stocks drive changes to other stocks. Having established that performance outcomes depend on the quantity of key stocks, and that those stocks accumulate and deplete through in-flows and out-flows, the last question is what drives the flows that fill or drain the stocks? ***Existing stocks*** drive flows into or out of other stocks – sales people win customers, for example, and too-few service staff leads to customer losses. Some ***decisions*** influence stocks' flow-rates (marketing spend wins customers) while other decisions simply *are* those flow-rates (staff hiring, for example). And of course, ***external factors*** influence flow-rates, competition and economic conditions may change the rate at which we win or lose customers or staff.

The interdependence between existing stocks and their own flow-rates cause ***feedback*** which may either accelerate change or hold it back. Existing customers can drive the win-rate of new customers through word-of-mouth mechanisms, but that win-rate may be self-limiting if there is inadequate capacity to serve the demand they generate.

This section has offered only the briefest summary of the principles behind working, quantified models of organisations and their performance. For a more substantial explanation, see Strategy Dynamics Essentials (Warren, 2016).

A simple LBM example

To demonstrate how the principles above lead to a living business model, consider a very familiar example – a neighbourhood restaurant.

How a restaurant makes money. For simplicity:

Revenue ($/week) = *sales* (meals sold/week) * *average price* ($/meal)

Gross profit ($/meal) = *average price* ($/meal) – *cost-of-goods* ($/meal)

Gross profit ($/week) = *sales* (meals sold/week) * *gross profit* ($/meal)

Total operating costs ($/week) = *staff cost* + *energy & consumables cost* + *marketing cost* + *overhead cost*

Staff cost ($/week) = *number of staff* * *staff-cost per person* ($/person)

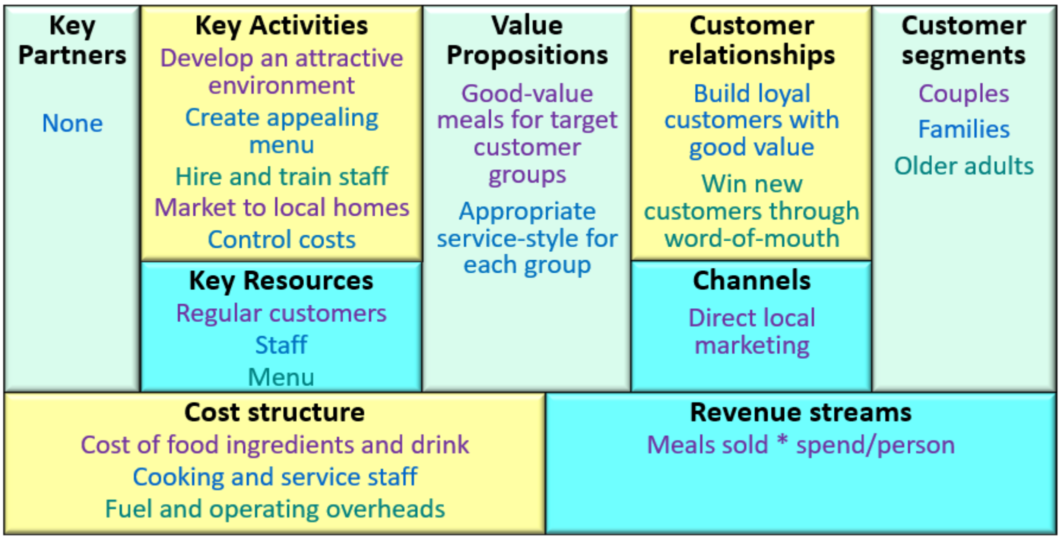
(*For simplicity, the costs of energy, consumables and overheads are assumed to be driven by the number of meals sold and by the restaurant size.*)

Operating profit ($/week) = *Gross profit – Total operating costs*

Note that we are looking at performance on a ***weekly*** basis, rather than for longer periods, because that is the pace at which demand conditions and the restaurant's operating performance change, and also the pace at which management can respond to manage the strategy with changed decisions.

A typical business model. The most popular tool for defining business models is the ***Business Model Canvas*** (BMC; see Osterwalder and Pigneur 2010). Figure 1 offers an example of such a BMC for this type of restaurant.

Figure 1: Business Model Canvas for the local restaurant's strategy



Such BMC specifications of a business strategy may be left at the simple summary shown in figure 1 or extended with more detailed definition of the various elements. However, much more is needed if SMA is to assist with defining, implementing and managing strategy and performance. First, every element must be specified with sufficient clarity to be quantifiable, and then measured continually. Next, the nature and strength of the inter-relationships between all those items must be estimated.

The restaurant's non-financial resources. The critical items to define and quantify first are the non-financial asset stocks, or resources, and any restaurant features exactly the set of common strategic resources listed earlier …

The restaurant has ***customers*** – a population of more-or-less regular guests who visit with some average frequency. One-time customers may also feature, but typically contribute very little to sales (*an element that can be recognised separately in the eventual model if necessary*). Those customers conform to the definition of any asset stock – their numbers are increased by winning new customers and decreased by losing current customers.

Figure 2 shows how the Stock of customers is changed for a single week by the flows of customers won and lost. (*Think of the box as a tank containing customers and the circles each side as pumps, pushing customers through the pipes at different rates*).

Figure 2: How restaurant customer numbers change for a single week

Those customers drive sales through the frequency with which they use the restaurant. If 1,000 customers visit on average once every 5 weeks, then sales are 200 meals per week. Customers' purchase frequency may be influenced – they will visit more often if they have a good experience – but it is in part an ***external*** factor – people typically go out for meals only so often.

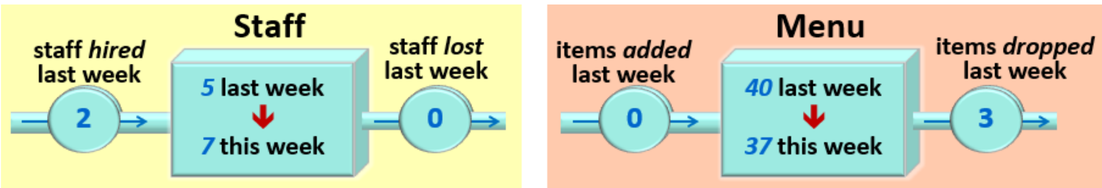
How might these numbers be found? Ask customers "*When did you last visit?*" The answer for repeat customers tells you their frequency, and those saying "*This is my first visit*" are customers won … from which customers lost can be worked out. In practice, such research needs to be sensitively done, to avoid causing annoyance!

Customers are ***won*** by marketing spend and by word-of-mouth recommendations. Customers are ***lost*** due to poor value-for-money, reflecting how they feel about the menu of products, service quality, and waiting time, in balance with the price of a typical meal.

The restaurant has ***staff***. Staff are added if we hire more or lost if we choose to cut staff numbers. These are both decisions in our own hands, so are not dependent on other resources in the system.

It also has a ***product-range*** in the form of its menu. A wider menu allows the restaurant to reach a larger potential customer-base (an ***external*** factor) and may also increase customers' visit frequency. This stock is changed by our choice to add new items or drop less popular dishes.

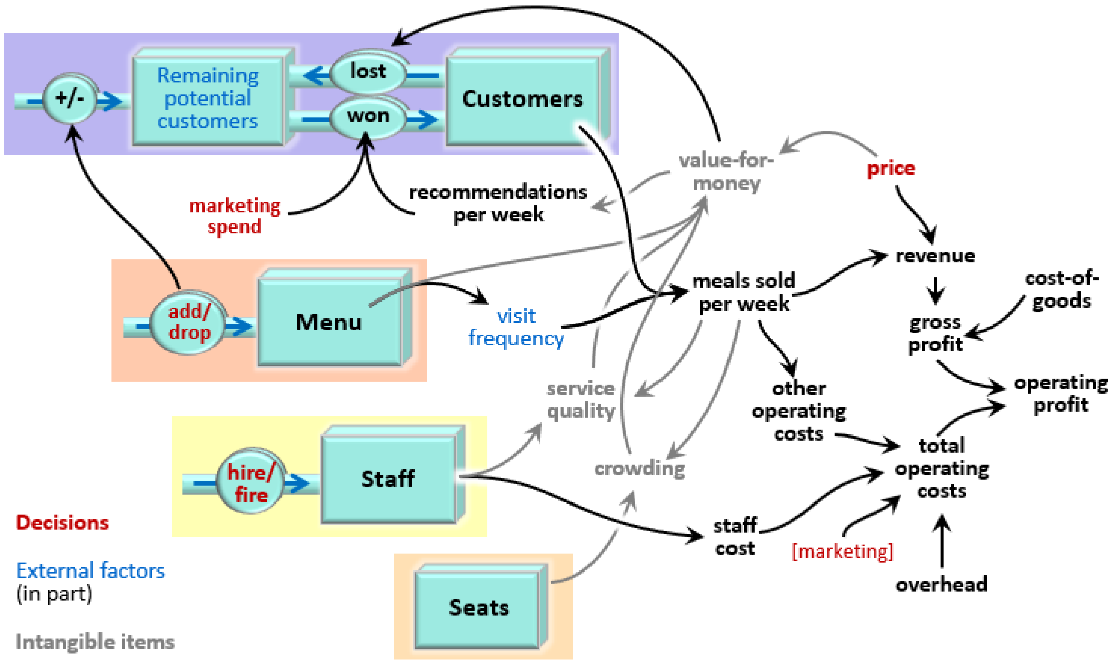
Figure 3: How the restaurant's staff and product range change



The restaurant's ***capacity*** is simply the number of seats it provides, which determines its maximum throughput of meals sold per week. This is rarely changeable in the short term.

How resources drive performance – and the growth or loss of other items. Figure 4 shows how the restaurant's resources are connected by causal relationships, both to each other and to the performance outcomes (revenue, costs and profit). Word-and-arrow diagrams are widespread in management frameworks, but here the linking arrows mean that each item can be ***calculated*** or ***estimated*** from those on which they depend. For example, *meals sold per week* can be calculated from *Customers* and *visit frequency*, and *service quality* can be estimated from *meals sold* and *Staff*.

Figure 4: How the restaurant's non-financial resources, decisions and external factors are connected



(*Figure 4 is a simplification of the full living business model for the restaurant – many intermediate items are left out. Note that such qualitative diagrams* ***do not*** *feature in the most reliable and effective modeling which works entirely with quantified items and relationships – see below for more on this "agile" process.*)

The working model. A working simulation of figure 4 requires:

- a weekly ***data-series*** for each item – think of this as a column of values in a spreadsheet
- a ***formula*** inside each item to calculate or estimate its value in each period from the items linked to it – think of this as the calculation inside each cell of that spreadsheet column.

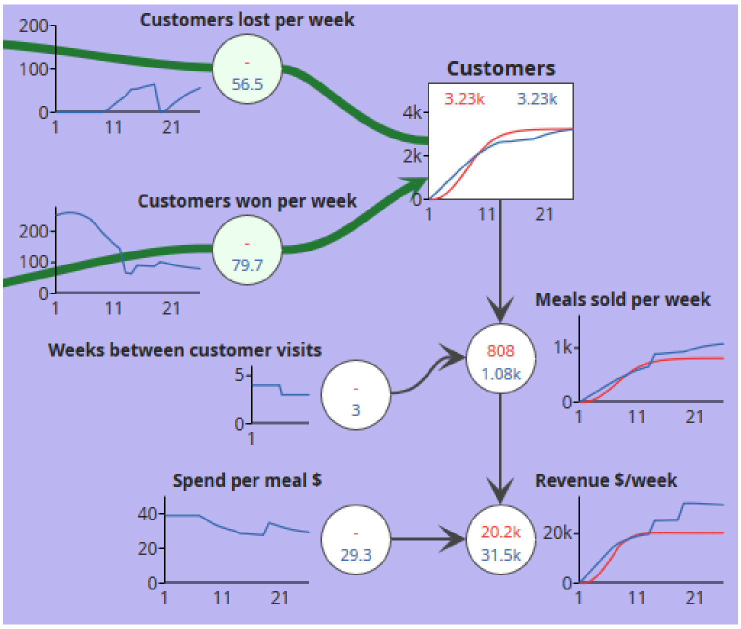
Figure 5 displays a small section of the working model, showing how the restaurant's sales and revenue change over its first 26 weeks of trading, driven by the changing number of customers. This in turn depends on the win- and loss-rates, a process that repeats for every period. Values displayed are for the final point in time (week 26). The scenario starts with the restaurant offering a limited menu, few staff (to keep costs down), and high marketing to win new customers, then ...

- in week 13, it cuts all marketing, because the restaurant is getting full and recommendations are bringing in more new customers
- ... and adds new menu items to raise customer satisfaction and reach new customers
- in week 18, adds more staff to fix poor service quality and cope with higher demand

By week 26, then, the restaurant has just over 3,200 customers, and is still winning more than it is losing. On average, each person visits once every 3 weeks, generating sales of 1080 meals/week. An average spend of $29.30 per meal leads to revenue of $31,050/week (*$31.5k, where 'k' = thousands*).

The full model is shown in figure 6 and the full working simulation can be accessed and explored at sdl.re/BMrestaurant4d. Although this model may be an unfamiliar view of a business analysis, it is simply the result of continuing the principles noted above, and is actually quite small compared with typical corporate spreadsheets whose structures are far less transparent.

Figure 5: How the restaurant's sales and revenue are linked, quantitatively, in the working model to the changing number of customers.



Fulfilling SMA requirements.

First, note that the model in figure 6 has important advantages over spreadsheet-based approaches. "*What causes what*" is crystal-clear, and because only linked items can be used in any item's calculation, cell-reference errors are impossible. Every item can display its time-chart, so it is clear how its direction-of-change is being caused by changes to its causal factors.

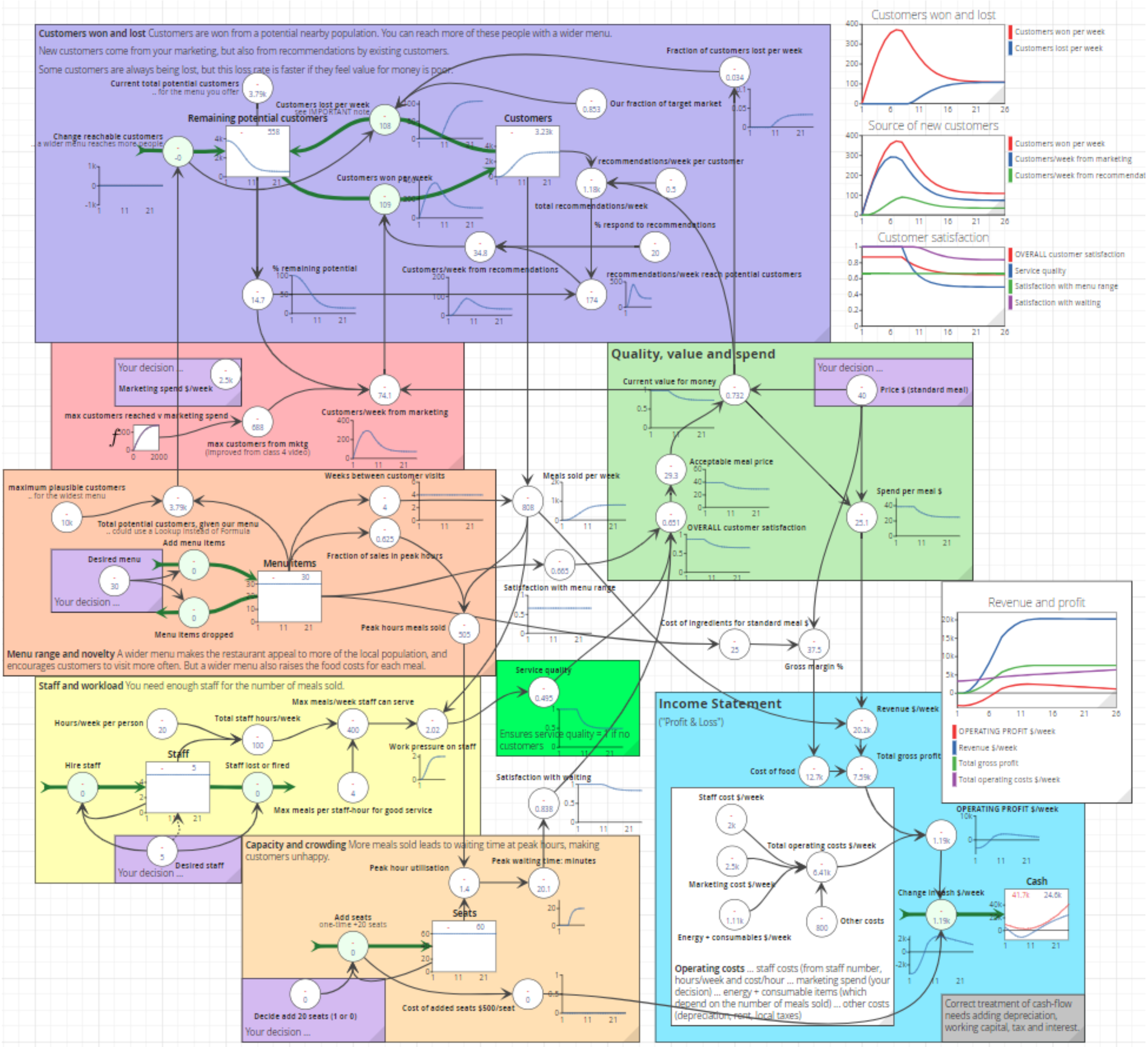
The red time-series can hold real-world data for an on-going business, so the model can be continually validated – *if the blue line does not match the red line, something is wrong*! Those real-world values can continue into the future, as in this case, to show whether the strategy can hit its objectives.

Each item's formula uses the actual names of the items on which it depends, such as `Meals sold week = "Customers" / "weeks between customer visits"` … not a set of abstract cell-reference codes. Any item for which a math calculation is not possible can be estimated from those on which it depends by using "look-up" functions – for example, the declining impact of ever-increased marketing spend in this case.

Beyond these practical benefits, such dynamic models fulfil all the requirements to make truly SMA achievable.

- Every item in the model, including all non-financial factors, is ***rigorously defined***. Not only are the resources and their flows entirely clear, but the quantification and calculation of all other items ensures that these too are clearly specified. Furthermore, every item is familiar to everyone involved in the business. The very act of building the model eliminates ambiguity and disagreement between people about what terms mean. Here for example, we have "*meals sold per week*", not just "*sales*"

Figure 6: Screenshot of the full restaurant business model



- The same rigour applies to relevant ***external factors*** –the number of potential customers in the catchment population for our style of restaurant, and how that number might vary as we extend the menu (*add children's meals, for example, and families are added to the potential*). The model does not yet include competitors, but easily could do so – simply replicate the entire structure and make each competitor pull customers from the same potential population. (*Clearly, the average competitor will end up with fewer customers than a single restaurant*!) The competition model can also capture the behaviour of some customers who allocate visits between competing restaurants, rather than using one restaurant exclusively.
- The model clearly specifies the ***arithmetical relationships*** by which those internal and external factors drive performance outcomes, both financials and non-financials, such as service quality.
- The model formulates how those same factors ***interact*** with each other to cause the system itself to change over time. Adding service staff improves any inadequate service quality, for

example, which would slow the rate at which customers are lost and raise the rate of recommendations to new customers.

- All relevant factors and relationships are combined into a ***working, quantified model*** that replicates the organisation's operating performance and development. In practice, the real-world time-series data (the red values) are updated every week, and the model's relationships checked to ensure that the simulation (the blue time-series) accurately mimics the observed behaviour.

Further potential developments. This example is of course a simple demonstration of how the basic principles of system dynamics can lead to a dynamic simulation model capable of fulfilling the requirements for SMA. Many further developments are possible.

This model could run on ***shorter time-units*** – using daily data, rather than weekly for example, in order to assess the impact of differing day-of-week demand patterns or to evaluate options to boost demand on quiet days. (*If we go to still shorter units, such as hours or quarter-hours, then numbers start to get small, and specific events become more significant, rather than aggregate patterns – the arrival and departure of individual customers for example. If that detail is required, other simulation tools may be more appropriate, such as discrete-event or agent-based modelling.*)

It may be useful to examine the capture, retention and demand of different ***segments*** of customers, splitting out families or older adults, for example. This is easily done by replicating the upper-left section of the model for as many groups as may be required.

Much more ***financial detail*** can be added. The purpose of this demonstration was to highlight the non-financial elements of the business system, but all other financial considerations can also be added – capital investment, depreciation, debt and interest, working capital, tax and so on. It may also be useful in some cases to include ***non-strategic*** factors, such as orders or inventory (in physical terms as well as value).

Any desired ***ratios or other indicators*** can be added, and the model used to show how and why these, too, are changing over time. However, care is needed not to create confusion by adding unnecessary indicators to what is already a complete explanation of business performance. The model actually ***is*** a balanced scorecard, including everything necessary and sufficient in order to enable SMA.

Policy rules can be added to the model, to automate key mechanisms and to test the impact of alternatives. For example, adding or cutting staff numbers can be driven by the level of service quality and/or by a staff-cost ratio rule.

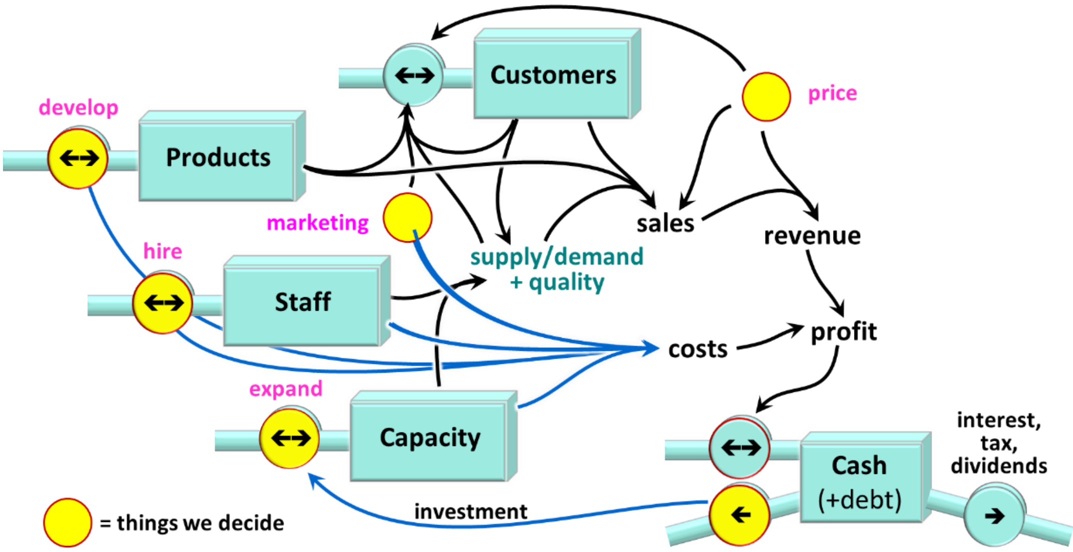
The model is easily replicated for a ***multi-unit business*** such as a chain of restaurants (or in other cases for different product-groups, geographic markets and so on). A "parent" model can aggregate these sub-models, just as the front sheet of a work-book may aggregate sheets for each individual unit.

The bigger opportunity from model-based SMA

A generic architecture. Figure 4 is a high-level system architecture describing how ***any*** neighbourhood restaurant functions. The numbers and relationships will differ vastly between contrasting cases, but this model is rigorous and reliable for all examples. Small modifications can adapt the model to any town-centre unit, road-side unit or take-away unit.

Figure 4 is also a sector-specific -case of a still more generic architecture that describes how businesses in most sectors work (figure 7). Profit comes from revenue minus costs (*including cost of goods where relevant*). Sales are driven by customers, who are are won or lost by price, marketing, quality and by the appeal of the product range. Sales can only be achieved if capacity is adequate. Costs are driven by either ***having*** resources (notably staff and capacity) or by ***building and retaining*** those resources (products and staff). Profit (strictly, cash flow of course) adds to the cash resource, some of which is paid out in interest, tax and dividends, but some is re-invested to raise capacity.

Figure 7: The generic strategic architecture of an enterprise



As noted earlier, certain industries require adjustments to this architecture. In many cases, the system includes both intermediate and final customers and the interdependencies between those groups. Two-sided businesses feature complementary customer-groups; for example, subscribers and advertisers (media and social-media), or buyers and sellers (eBay, AirBnB …). In service-based firms, staff *are* the capacity. Construction-based and advisory firms may need the addition of projects; natural-resource firms include reserves; and so on.

Template models. The generic cross-industry architecture means not only that industry-specific architectures can be easily specified, but that template models – equivalent to the restaurant example – can also be constructed. See for example, simple models for a basic IT-support business and for a consumer brand. Both of these models also illustrate that a LBM need not make explicit every significant stock – each of these models focuses on the market-place success of the business, so does not pay attention to the cash-resource. For the consumer brand, production and distribution are out-sourced, so the model need not include the physical capacity of either activity.

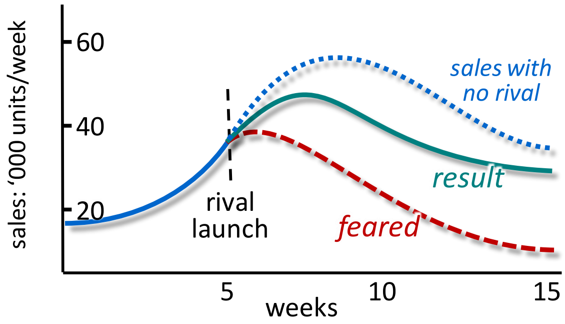
Functional or department plans. The restaurant example concerned an early-phase plan for a whole business, albeit a small and simple one. That plan could continue to be used indefinitely, beyond the start-up period, as the basis for the unit's on-going management. It is therefore an example of a ***whole-business*** model, used for continuous ***planning and control***.

However, LBMs are equally useful for specific functions or teams, any of which is only a part of the whole enterprise. An HR function might have a LBM of the organisation's staffing development, capturing how numbers of people have changed and need to change into the future. This would be split by team and seniority level, and could also capture changes in skills and experience. Similarly, living models are useful for product-development plans, for long-term planning of investment and maintenance of physical assets, or for information-systems.

Note, though, that any such function-specific plan will need to make explicit any dependencies on other parts of the business, and any consequences for those other parts. The staffing plan, for example, will need to be driven by expected developments in labour-requirements of each team, and will inform those teams of any likely constraints arising from staffing issues.

Plans -v- issues. LBMs can also be used to plan, implement and control strategies for dealing with one-off issues or initiatives. These may be small or large, and span short or long periods of time. Take, for example, the case of a rapid and aggressive competitive threat faced by a pharmaceuticals product. (*See figure 8, where the growth and decline in all scenarios reflects the highly seasonal demand for the product*). A simple model helped assess pricing and other tactical options over the expected 15-week peak of the episode – a case that fits all the criteria for requiring SMA support but that demands far more than financial techniques can offer. LBMs can handle numerous other challenging issues; raising service quality (on any relevant measures), reducing too-fast staff turnover, launching a new product or service and so on.

Figure 8: Limiting the competitive threat in a seasonal pharmaceuticals market.



Larger-scale issues and challenges also require the holistic, dynamic capabilities of a LBM. Examples include entering a new market, designing and controlling complex construction projects, planning and implementing change programs, evaluating and integrating an acquisition, or assessing any type of ***strategic investment decision***. All such cases are "systems" consisting of exactly the same kinds of factors we find in enterprise models. The relevant LBM can assist in the initial assessment and planning of all the non-financial elements of the plan, linked rigorously to the critical financial implications. Furthermore, that same model can provide continual monitoring, control and adjustment of the evolving situation.

Developing a capability for Living Business Models

The restaurant example above features the most appropriate method for developing and using Living Business Models – system dynamics (SD), developed in the 1960s at MIT (Forrester 1968; Sterman 2000). SD is one of three simulation methods for modeling organisations' performance, the others being agent-based modeling (ABM) and discrete-event simulation (DES) – see Maidstone (2012). DES has a substantial heritage and is very widely used for modeling discrete events concerning individual entities moving through a process, such as queuing cases and production or supply-chain systems. ABM is ideal for modeling the actions and interactions of autonomous agents in order to assess their effects on a wider system. It is especially powerful where geo-spatial phenomena are important, such as the spread of diseases.

SD, in contrast, is a continuous simulation method that addresses interactions between related *populations* of people, things or materials – for SMA purposes, these are the asset stocks we have termed "resources". SD lacks the entity-specific feature of ABM or DES methods, but has the advantage that its models can be compact and built quickly, while efficiently capturing interactions between diverse types of resource. This makes SD ideal for strategic planning and management of longer-term challenges concerning multiple parts of a complex system. There can be benefits from combining SD with DES or ABM methods in hybrid models (Mustafee et al 2015).

Leverage existing skills. A further advantage of SD for SMA purposes is the easy translation of standard spreadsheet modelling skills into simulation modelling. The conceptual equivalence was already noted – model elements and links correspond to spreadsheet columns and cell-references.

Indeed, it is theoretically possible to build a SD model in a spreadsheet. However common features of real-world systems make spreadsheet modelling of such cases impossible in practice, notably the multiple interdependencies and resulting feedback, as well as threshold effects and intangibles.

An "agile" modelling process. Although SD is a long-established science, its perceived difficulty has held back its uptake. Traditionally, modelling starts by identifying the full scope of the issue of concern, then developing with all relevant stakeholders a comprehensive but qualitative diagram of how its elements are thought to be linked. The resulting "causal loop diagram" (CLD) is then converted into a quantified model. Much time and judgement are required by this process, both by the modeller and by the participants they are helping, which may lead to erroneous and unreliable models.

Ideally, two equally skilled professionals should follow the same rigorous and unambiguous process to model a plan or issue and end up with near-identical models. To achieve this aim, there is now an "agile" modelling process – named for its adoption of certain principles from the agile approach to software development. The method starts from a ***very*** small but working, quantified model, which is then developed in small steps and continually validated. (See the short practitioner guide at sdl.re/AgileSD).

Software. Several powerful and well-established software tools exist for SD modeling - see systemdynamics.org/tools. The demonstration model and other examples mentioned above use the browser-based Sysdea software (see Sysdea.com and sdl.re/sygfull), which is quick to learn and use. It provides time-charts on all significant items, and displays real-world time-series alongside simulated results, features that cut development time and error-rates.

Less work, not more. A common disincentive to adopting any new technique is the fear that it will simply add to existing workloads, but that is not the case with dynamic modelling. If some SMA task needs to be done that includes time-based features, it is ***easier, faster and more reliable*** to assemble a dynamic model than it is to do a more limited and less-useful analysis by conventional means. Naturally, as for any new skill, some investment of time and effort must be made, but the commitment needed to start modelling simple but valuable real-world cases is modest.

Integrating other SMA tools and methods (See Attachment 1).

The CIMA report (Pitcher, 2015) lists the most important techniques already commonly used for SMA. Note that most of the listed tools focus (understandably) on cost-related analysis. These analyses are easily embedded in LBMs, either for formulating relationships in the models or as outputs of interest that the model generates. The key contributions this integration provides are to connect those financial indicators to the non-financials that drive them, and to show with confidence how and why those metrics have changed up to the present time, and may change further into the future.

Conclusions and next steps

This paper has explained that ***truly*** strategic management accounting is very wide in scope and imposes demanding requirements for any tools and techniques that may be used, especially in encompassing ***all*** significant elements of the organisation and its environment. However, it has also explained a rigorous, reliable and practical set of principles that make those demanding requirements achievable. These arguments make the case that the building of dynamic, living business models is a capability that any management accountant should, and can, possess.

Useful next steps include the following:

- See more on the power and value of Living Business Models, including some success cases, at sdl.re/PowerOfModels and other videos at youtube.com/strategydynamics.

- Take the free online classes to see how to build the demonstration model in this paper.
- Download the free practitioner guide on the agile model-building process.

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Attachment 1: Connections between Strategic Management Accounting techniques and Living Business Models

The following table lists SMA techniques identified in the CIMA report on SMA (Pitcher 2015) together with the report's *brief explanation for each*. The table then explains briefly how each tool relates to dynamic modelling.

Technique	*SMA definition* and relationship to Living Business Models
Activity-based costing	*An approach to the costing and monitoring of activities which involves tracing resources consumption and costing final outputs. Resources are assigned to activities and activities to cost objects based on consumption estimates. The latter utilise cost drivers to attach activity costs to outputs.* Dynamic models can include all such cost items and activities, and thus offer a continuous picture of how activity-costs are changing. Note, however, that most costs (except most notably cost-of-goods) are driven by the ***existence*** of a resource, such as staff, or by effort to ***move*** a resource into or through the business (hiring and training of staff, marketing to win customers, and so on). In most cases, these costs are independent of any output that the organisation produces. Employed staff are usually paid, whether or not they do anything!
Attribute costing	*An extension of activity-based costing using cost-benefit analysis (based on increased customer utility) to choose the product attribute enhancements that the company wants to integrate into a product*. Dynamic models can monitor product-attribute costs from the time the product or service is launched. However, they can also provide the time-based resources, activity rates and associated costs for the process of *developing* a product or service, or an enhancement to an existing product or service. They can thus provide a full product development plan and associated costs, revenues and returns to assess which products, services or features to choose. Any "customer utility" is modelled explicitly in its own terms (e.g. customers' rating of product performance, reliability and operating cost).
Brand-value budgeting	*Brand valuation assigns financial value to the equity created by the name or image of a brand. It can be represented as the net present value of the estimated future cash flows attributable to the brand*. Value (Koller et al 2010) can be computed from any dynamic model – for the enterprise as a whole, for alternative strategies, for an acquisition or project, or for a brand. The first contribution of a dynamic model is to validate that the system is ***capable*** of the projected outcomes. However, note that a brand's value is unavoidable dependent on the rest of that system of which it is a part – the brand will have a quite different value if owned by a firm with a larger, stronger sales force than the current owner. A dynamic model can therefore offer an accurate assessment of a brand's value to alternative owners.

Technique	*SMA definition* and relationship to Living Business Models
Capital budgeting	*The process of selecting long-term capital investments*. One of the greatest challenges in assessing the potential value of alternative investments is estimating the future performance improvements that each may deliver. The value of a rigorous dynamic model comes from its ability to validate that the system that the investment will facilitate can indeed generate the projected outcomes.
Competitor cost assessment	*A technique in which the competitor cost per unit is attempted to be ascertained from available information*. Given a sound dynamic model of our own business, it is quite possible to modify a copy to replicate the likely performance of a competitor. This requires significant competitor-intelligence, most notably on the scale and quality of resources (as defined in this paper). Such a model can then be used to estimate the impact of alternative competitive tactics, such as the targeted capture of certain customers or segments, or the launch of a product against specific competing products.
Competitive position monitoring	*Monitoring the market position and competitive strategy (market positioning) of the key competitors*. Competitive positioning can be a static, one-time assessment of their key choices about the customer-types competitors choose to serve, with what products or services (defined by the specific customer benefits they offer), and how they choose to do so. This is typically a high-level, qualitative assessment. As noted above, a dynamic model is capable of estimating a competitor's likely future performance, based on its chosen positioning and policies. A model can then estimate the potential impact of any ***changes*** the competitor may make, such as launching a modified product to capture a new customer segment.
Competitor appraisal of financial statements	*Looking for strengths and weaknesses in the competitors' financial position*. If those financial statements include information on the non-financial resources of a business, and if that business is a single-activity firm, then much strategic value can be gained from pushing this appraisal through to a working model of the competitor's business. The best examples of this are in the low-fare airline industry, where leading firms publish data on passenger volumes, staff, aircraft, airports and routes, plus key operational data such as numbers of flights. Companies rarely publish such comprehensive information on non-financial resources, and many consist in any case of multiple business units that are not adequately disaggregated. This significantly limits the opportunity for estimating competitors' likely strategy and performance from published reports alone. However, models that add estimates of the competitor's non-financial resources may extend and add confidence to assessments based on financial analysis alone.

Technique	*SMA definition* and relationship to Living Business Models
Customer profitability analysis (CPA)	*CPA is the analysis of the revenue streams and service costs associated with specific customers or customer groups.* A dynamic model can incorporate exactly this analysis and show how the "quality" of the business is changing as the mix of customers or groups alter. Customer profitability is modelled as an "attribute" stock that grows or declines as customers of differing profitability are won or lost.
Integrated performance measurement : balanced scorecard (BSC)	*The balanced scorecard is a strategic planning and management system used to align business activities to the vision and strategy of the organisation, improve internal and external communications, and monitor the organisation's performance against strategic goals.* A sound dynamic models ***is*** a BSC, but with substantial improvements. The model's rigorous specification of all resources and intermediate factors, plus the validated numerical relationships between those items makes a dynamic BSC much more reliable. The simulation of how all these relationships are changing over time gives much greater insight than typical 'this-month-v-last-month' comparison. The result is a ***living*** BSC that can indicate not only how the health of all aspects of the business have changed up to now, but also how it will likely change into the future … e.g. "*Service quality is fine, but unless we start to hire 5 people/month we will have quality problems by month 4*". Lastly, a living BSC incorporates competitive and other external information, not usually included in BSCs.
Life-cycle costing	*Life-cycle costing is the profiling of costs over the life of a product, including the pre-production stage.* A dynamic model can provide exactly this analysis, but with more detailed and rigorous foundations reflecting the costs of adding and sustaining the resources required for product development, marketing and sales efforts. It can also provide a ***continuous*** picture of how those factors and costs are evolving in reality, relative to expectation, and it can be extended to include the customer-acquisition, sales and revenue projections.
Quality costing	*The concept of quality costs is a means to quantify the total cost of quality related efforts and deficiencies. It can be broken down into appraisal costs, prevention costs, internal and external failure costs.* This is a situation where a single-issue dynamic model is useful. The model would capture the quality-related events and associated staffing and equipment needed to maintain and fix quality issues for a product or product-group. Once again, the advantages are a rigorous system-wide explanation for quality and costs and a picture of how these are changing over time. To this reporting model can be added investment of effort and spending that will improve quality, providing a continuous view of the ROI from such investments. A current example concerns the roll-out of IoT monitoring devices to transform the maintenance of components in complex industrial settings, such as power networks or oil processing facilities..

Technique	*SMA definition* and relationship to Living Business Models
Strategic cost management	*Strategic cost management is the overall recognition of the cost relationships among the activities in the value chain, and the process of managing those cost relationships to a firm's advantage.* Strategic cost reporting falls naturally out of a dynamic business model and clarifies in particular the distinction between the costs of adding, retaining and operating each resource. Again, a dynamic model connects those costs to the resources and resource-changes that drive them, ensures a holistic view of the relationships between those costs-drivers, and provides a continuous picture of how and why those elements are changing, and may change in future.
Strategic pricing	*Strategic pricing takes into account market segments, ability to pay, market conditions, competitor actions, trade margins and input costs, as well as other potential factors affecting market position and demand for the product.* Dynamic models distinguish three critical customer behaviours – why they choose to ***become*** our customer, why we ***lose*** them and why they choose to ***buy more or less*** from us over time. All three behaviours are driven by a mix of factors, of which price is a key item. The model will exploit methods such as the "value curve" (Kim and Mauborgne 1997) or conjoint analysis to capture the relative influence of these factors on each behaviour.
Target costing	*Target costing is an activity which is aimed at reducing the life-cycle costs of new products, by examining all possibilities for cost reduction at the research, development and production stage. It is not a costing system, but a profit-planning system – the selling price and profit requirement are set during the research stage, thus creating a target cost.* Dynamic models offers the same benefits for this activity as noted above for life-cycle costing.
Value-chain costing	*Based on Porter's Value Chain analysis, a firm may create a cost advantage either by reducing the cost of individual value chain activities or by reconfiguring the value chain. Once the value chain is defined, a cost analysis can be performed by assigning costs to the value chain activities.* A dynamic model offers any set of margin and cost indicators required. If the value chain is to be reconfigured, the model can not only compare before-v-after value-chain comparisons but also project the ***path*** along which the business moves from 'before' to 'after', including any resources and costs needed to make that transition.

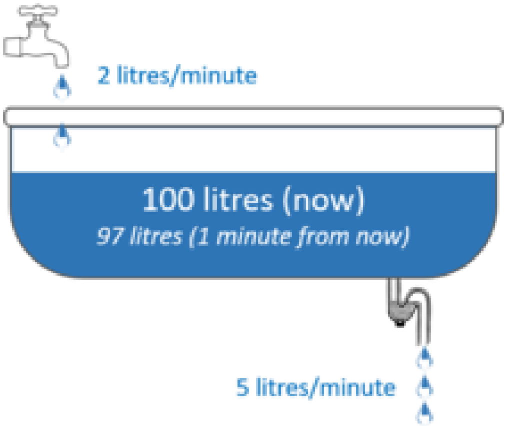
Attachment 2: What is an "asset stock"?

This is a general-purpose definition and explanation of asset stocks (not specific for a management accounting audience). *It is taken from a draft Wikipedia page, pending approval at the time of writing.*

An ***asset stock*** - or simply "Stock" - is a collection, group, population, mass or volume of materials or entities that accumulates or depletes over time. Familiar examples include the quantity of liquid in a tank, the amount of cash in a bank account (or debt on a credit card), the population of a country (or fish in a fishery, bears in a forest, etc), the inventory of goods in a store (often called the store's stock), and the quantity of CO_2 in the atmosphere.

The behaviour of asset stocks is explained by the "bath-tub metaphor" - changes to the level of water in a bath-tub reflect the interaction between the in- and out-flows. If the in-flow rate is faster than the out-flow rate, then the bath-tub continues to fill over time; if slower, then the bath-tub empties (figure 9).

Figure 9: How the rate at which water flows into and out of a bathtub changes the quantity or "Stock" of water each minute.



The defining characteristic of any asset stock is that the quantity of material or entities in that stock can only be changed by its flow-rates, or simply "Flows" - the rate at which new materials or entities are flowing in, and/or the rate at which existing materials or entities are being lost - liquid flowing into or out of the bath-tub or tank, cash flowing into or out of the bank account, people being born or dying, and CO_2 being emitted or absorbed. Asset stocks therefore "accumulate" and "deplete" (fill and drain) over time.

Mathematical properties

- The quantitative behaviour of asset stocks is axiomatic (indisputable) - it is not a theory or statistical finding; it simply ***is*** how these elements of the real-world behave. The quantity in any Stock at any point in time is ***precisely equal*** to the quantity in the Stock at a previous point in time, plus any amount that was added, minus any amount that was lost in the intervening period.
- This also means that the quantity at any point in time is ***precisely*** the sum of everything that ***was ever*** added, minus everything that was ever lost, since the asset

stock first came into existence - a bank account contains the sum of every dollar ever paid in, minus every dollar ever paid out since the day the account was opened. There cannot be any error in this relationship, so attempting a statistical "explanation" for the account balance is meaningless. And if statistical analysis cannot explain the quantity of any stock, then it also cannot explain anything that ***depends on*** that stock, such as the crime rate (which depends on the stock of criminals) or a company's sales (which depends on the stock of customers).

It ***is*** meaningful, however, to seek statistical explanations for the flow-rates, since these are instantaneously dependent on whatever causal factors are driving them. An important implication of this Flow-to-Stock relationship is that root cause analysis unavoidably breaks down at any point where an identified "cause" is an asset stock - that Stock ***is*** a root-cause at any point in time.

Units of measurement.

The units of an ***asset stock*** are only meaningfully measured at ***points in time*** and are "number of items" for discrete items (*people, fish, bears, inventory units*), or weight or volume for continuous-items (*litres of liquid, tons of* CO_2*, dollars of cash*). However, it may be useful to work out average Stock-quantities during a period, such as the average bank balance during a month, or the average population during a year.

In contrast, ***the in- and out-flow rates*** are measured for the ***period of time*** between the two times at which the stock's quantity is measured. The units for each flow-rate are therefore "items per period" (*people or fish per year, inventory units delivered or sold per week*), or "weight/volume per period" (*litres/minute, tons/year, dollars/month*). These relationships are captured by a differential calculus equation:

$$d(Stock)/dt = Inflow(t) - Outflow(t)$$

… where '*t*' is the period over which the change in the Stock is measured and '*d(Stock)/dt*' is the math notation for the net change in the Stock during period-*t*. The "*d …/dt*" is mathematical notation for the rate of change – the very small amount by which the Stock changes over a very small period of time.

"Integration" calculates how stocks change over time.

Although the differential notation is mathematically correct, the causal relationship is in fact the other way around - the flow-rates determine ***precisely*** the change in the Stock's quantity. (*A Stock may also influence its own flow-rates, as when water levels drive flooding or a bank balance drives interest-received. However, this is not necessarily so, except at the point where the Stock is empty - negative quantities of people or* CO_2 *are impossible, although a negative bank balance clearly is!*) This principle that Flows drive changes to a Stock's quantity requires the formulation to be reversed, leading to an integral equation (Sterman 2000, Chapter 6):

$$Stock(t) = Stock(t_0) + \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds$$

… where '*Inflow(s)*' is the value of the inflow-rate at any time '*s*' between the initial time 't_0' and the current time '*t*'. This is simply math language for "*The Stock/s value at some future time will be its value now, plus or minus the net sum of all flow-rates during all small periods of time between now and that future time".*

While this math may be beyond most people, the practical calculations involved are quite familiar. Table 1 shows the relationships between the balance (Stock) in a bank account and the payments into and out of the account each month (the Flows). The balance at the end of the month is equal to the balance at the start of the month plus or minus the net amount paid in or out. The end-of-month balance then becomes the starting balance for the next month, as is highlighted for the end of January and start of February.

Table 1: How amounts are paid in and out of a bank account each month change the account balance.

Month	Balance at start of month	Paid in during the month	Paid out during the month	Net paid in or out	Balance at end of month
	$	$/month	$/month	$/month	$
January	100	50	35	15	**115**
February	**115**	50	40	10	125
March	125	50	45	5	130
April	130	50	50	0	130
May	130	50	55	-5	125
June	125	50	60	-10	115
July	115	50	65	-15	100
August	100	80	70	10	110
September	110	80	75	5	115
October	115	80	80	0	115
November	115	80	85	-5	110
December	110	80	90	-10	100
January	100				

Note that these calculations could be done with any chosen frequency, to give the changing account balance each year, week, day or hour.

Implications

Asset stocks are fundamental to the behaviour of many systems, due to four critical roles they play (Sterman 2000).

- Stocks characterize ***the state of the system*** and its performance on any measure at any point in time, as the examples above illustrate. For example, *interest charges* on a credit card are driven by the *debt* on that card (the Stock), as is the interest-cost of Government debt. The *demand for food* and the rate of *waste*-generation are driven by the *population* Stock, the *supply of food* is driven by the Stock of *agricultural land*, the workload and cost of *health-care, schooling* and *crime-prevention* are driven by the Stocks of *patients, children and criminals* respectively, and so on.
- Stocks provide the system with ***inertia and memory.*** For example, today's national debt is *still* high in many countries because Governments had to borrow large sums in the 2007-08 financial crisis. Nothing that has happened since that time can undo those events.
- Stocks are the source of ***delays*** - if a customer buys an item today, it enters a Stock of outstanding orders and is only delivered to that customer after production delays and/or delivery delays. ***All*** delays involve asset stocks. There is no real-world

mechanism for any factor to influence another at a future point in time unless something (material or information) is stored in a Stock for the intervening period.

- Stocks ***separate rates-of-flow***, causing ***disequilibrium*** dynamics. If food could not be stored, for example, then the food consumption rate would have to match the food production rate.

In all cases, if the ***quantity of the Stock*** does not change (and other parameters remain constant), then the ***outcome*** of concern is also unchanged. And since changes to any Stock can only be caused by the related Flows, those Flows are the ***key policy levers*** that can change future outcomes - slow the rate of credit-card spending or accelerate the rate that debt is paid off, reduce the birth-rate, bring new land into agricultural production, deter young people from becoming criminals, and so on.

Challenges of understanding

Although the basic arithmetical relationship between a Stock and its Flows is essentially simple, its manifestation in practice can be ***non-intuitive***. It may be thought that slowing the rate of credit card spending would cause the credit card debt to fall, but it does not - it merely slows the rate at which the debt is increasing. The debt level will only fall if the repayment rate exceeds the sum of the spending rate and the rate at which interest charges increase. (*The same is true of efforts to cut Government debt*). Similarly:

- fish-stocks can only recover if the catch-rate is cut to ***below*** the rate of renewal (births minus deaths) for the fish population
- cutting the rate of CO_2 emissions will only slow the rate of increase for atmospheric levels of CO_2 if the cuts are great enough that the sum of human and other emission rates drops to ***less than*** the biosphere's absorption rate.

Changing flow rates make the resulting behaviour of asset stocks still less intuitively obvious. Figure 10 is taken from a working, quantified model of the bank account example that matches precisely the values in the table above. The behaviour of both flow-rates is simple - the in-flow has a step increase, and the out-flow shows a linear growth. But it is not at all obvious that these changes will result in the rising and falling balance shown in the stock. It is well-established that few people are able to work out the time-path behaviour of the stock in such cases, given simple information on the changes to the in-flow and out-flow rates (Cronin et al 2009).

Figure 10: A working quantified model of changes to a bank account over 12 months

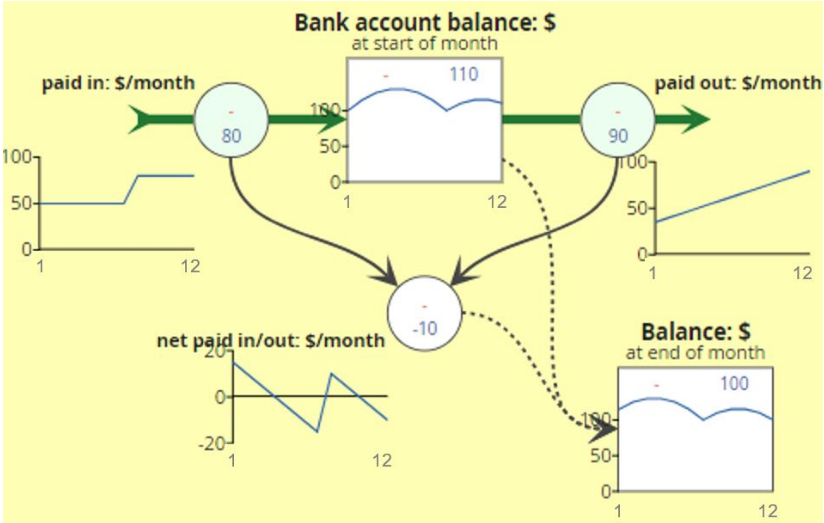


Figure 10 is a quantified representation of the "bath-tub metaphor". Simply replace "dollars" in the model with "litres of water" and the exact same model shows how the quantity of water in the bath-tub rises and falls as the rate of water entering and leaving the bath-tub change over time.

Recognition and application

The critical role of asset stocks was first recorded in ancient Mesopotamia where settled cities started to store and distribute grain and other goods. Checking the additions to those stocks at harvest time, the distribution of those stocks during the rest of the year, and the changing level of the remaining stocks required stock-and-flow calculations, a practice that formed the basis of modern-day accounting. The recognition and exploitation of stock-flow relationships was also required in ancient times for engineering purposes, especially irrigation and flood control, for example in the Nile valley.

With the Industrial Revolution, more complex movements of raw materials and goods required those same stock-flow principles from Mesopotamian history to be replicated for all cases of inventory or stock management and at each stage of all supply chains. That period also saw the development of modern engineering disciplines, in which mathematical manipulation of stock-flow relationships are critical. Chemical engineering, in particular, relies on controlling the movement of liquids between vessels, driven by pumps and controlled by valves. Information on the levels of such vessel liquids, and on the rates at which those liquids are moving is used to adjust the pumps and valves that control those flow-rates. This exploitation of information feedback is the central feature of control engineering, which can also be traced back to ancient times, and is now fundamental to many technical fields.

The understanding and control of stock-flow mechanisms have thus been fundamental to the management of materials, goods and money for many millennia. Certain other fields, such as demography, are also highly reliant on understanding and analysis of stock-flow principles. Population dynamics is essentially the analysis of population stocks and flows (births, deaths, migration and ageing).

In recent decades, the role of accumulating asset stocks in other fields has been increasingly recognised and exploited, such as in environmental change and policy (Ford 2011), the spread of infectious diseases based on stocks and flows of susceptible, infected and resistant individuals (the SIR model), and public-health policy (Homer and Hirsch 2006).

The recognition and exploitation of asset stocks' importance to other fields has, though, been somewhat slower. For example, while any economy clearly consists of many interdependent stocks and flows - jobs and net job-creation, capacity and investment-driven capacity-changes, quantities and flows of money, trade flows, populations and demographic changes - the study of macroeconomics pays limited attention to rates-of-change and offers little formal representation of those stock-flow relationships (Green 2011). Enterprises - whether for-profit corporations, non-profit organisations or public-services - are also made up of interdependent stocks and flows, such as customers, staff, production-capacity, products and services. Yet the study of enterprise management, especially long-term strategic management, pays little attention to the mechanisms and implications noted above, even though its importance has long been noted 1989 (Dierickx and Cool 1989). The strategy dynamics method, however, does offer a stock-flow-based solution in that field (Warren 2008).