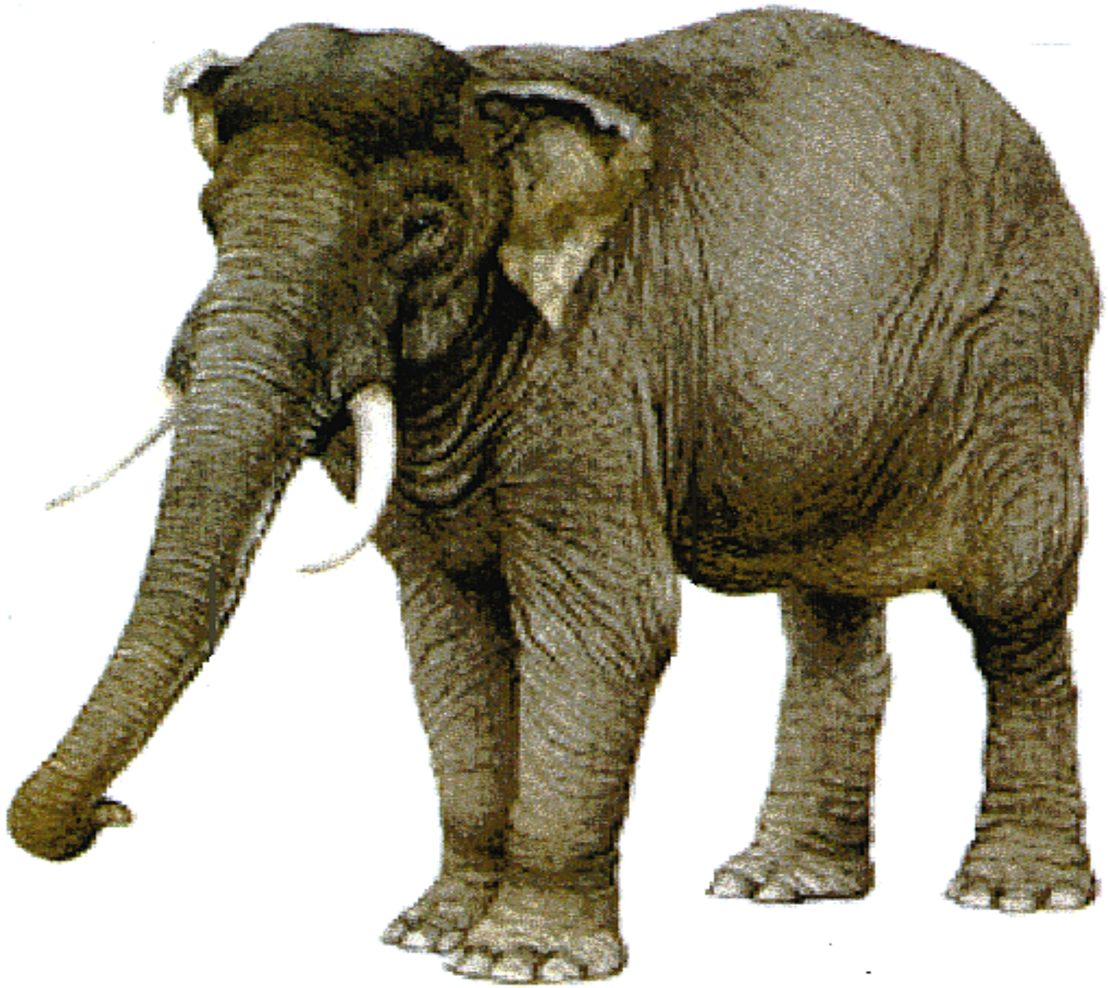
The systems perspective

The Silver Bullet Machine Manufacturing Company Limited

2014



What do you get if you cut an elephant in half?

You do *not* get two half elephants.

Rather, you have taken a system that worked quite well, and transformed it into two systems that don’t work well at all.

The techniques of analysis and disaggregation have been very powerful in helping us understand many systems - indeed the whole of science and engineering is based on this principle. Some systems, though, are not susceptible to this approach - the act of carving the system into ever smaller parts destroys the very subject of interest.

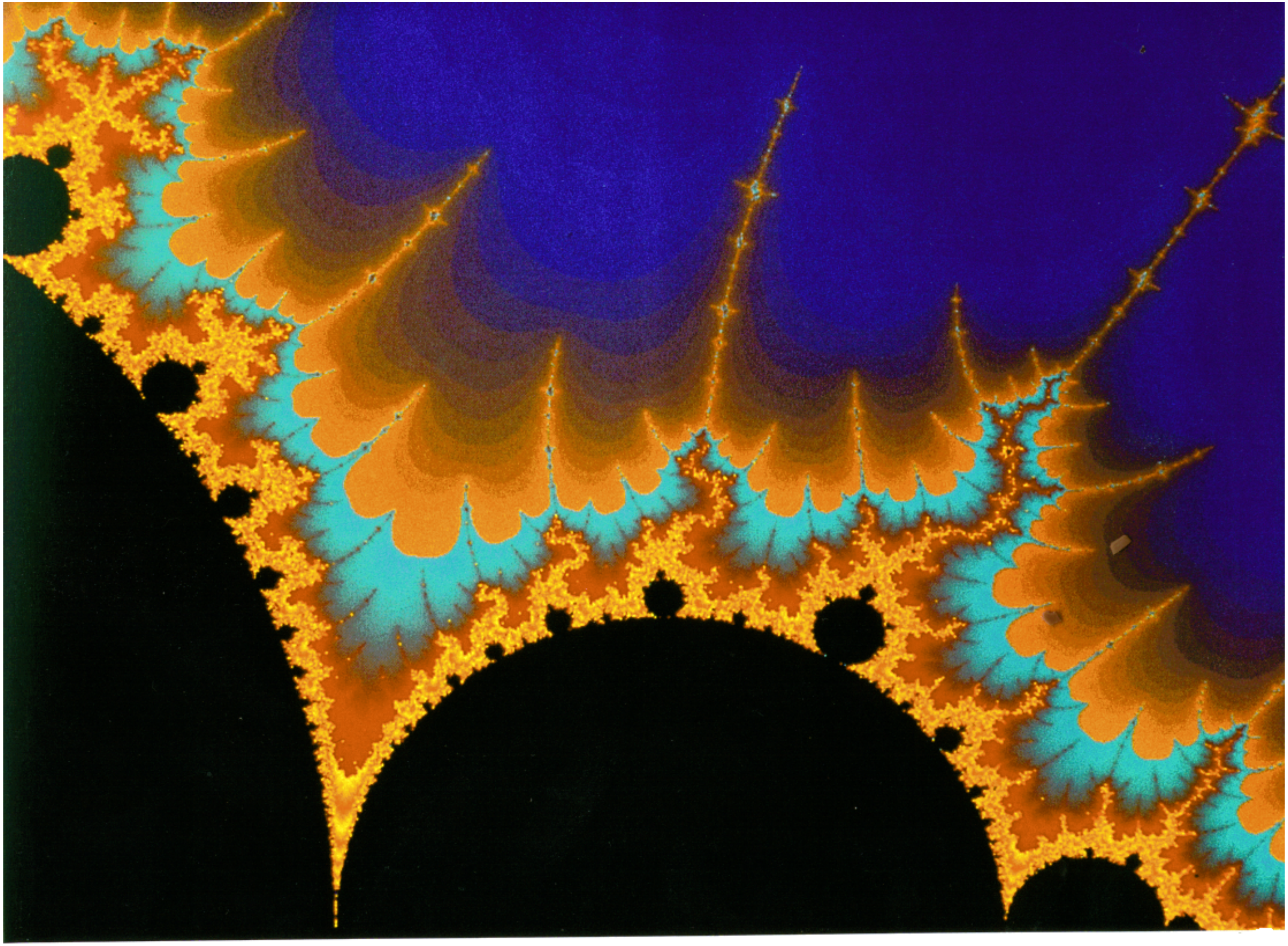
Connectedness

What key characteristic of a system determines whether it can successfully be broken down into its component parts, or is destroyed?

Connectedness

If an integral part of the system is the *connectedness* of the component parts, then breaking the system into its component parts necessarily destroys the essence of the system.

That's why analytic, scientific techniques have been relatively unsuccessful in helping us gain insights into the behaviour of human systems - communities, teams and organisations are very strongly connected.



Taming complexity

If the familiar tools of scientific analysis are ill-equipped to help us gain an understanding of complex, highly connected systems - like a business - what are we to do?

Do we continue to use our hammer, even if we know our problem is not a nail?

Do we give up?

Or is there another tool … a tool that recognises complexity and connectedness … a tool that does not demand disaggregation, but which embraces a complete, holistic approach?

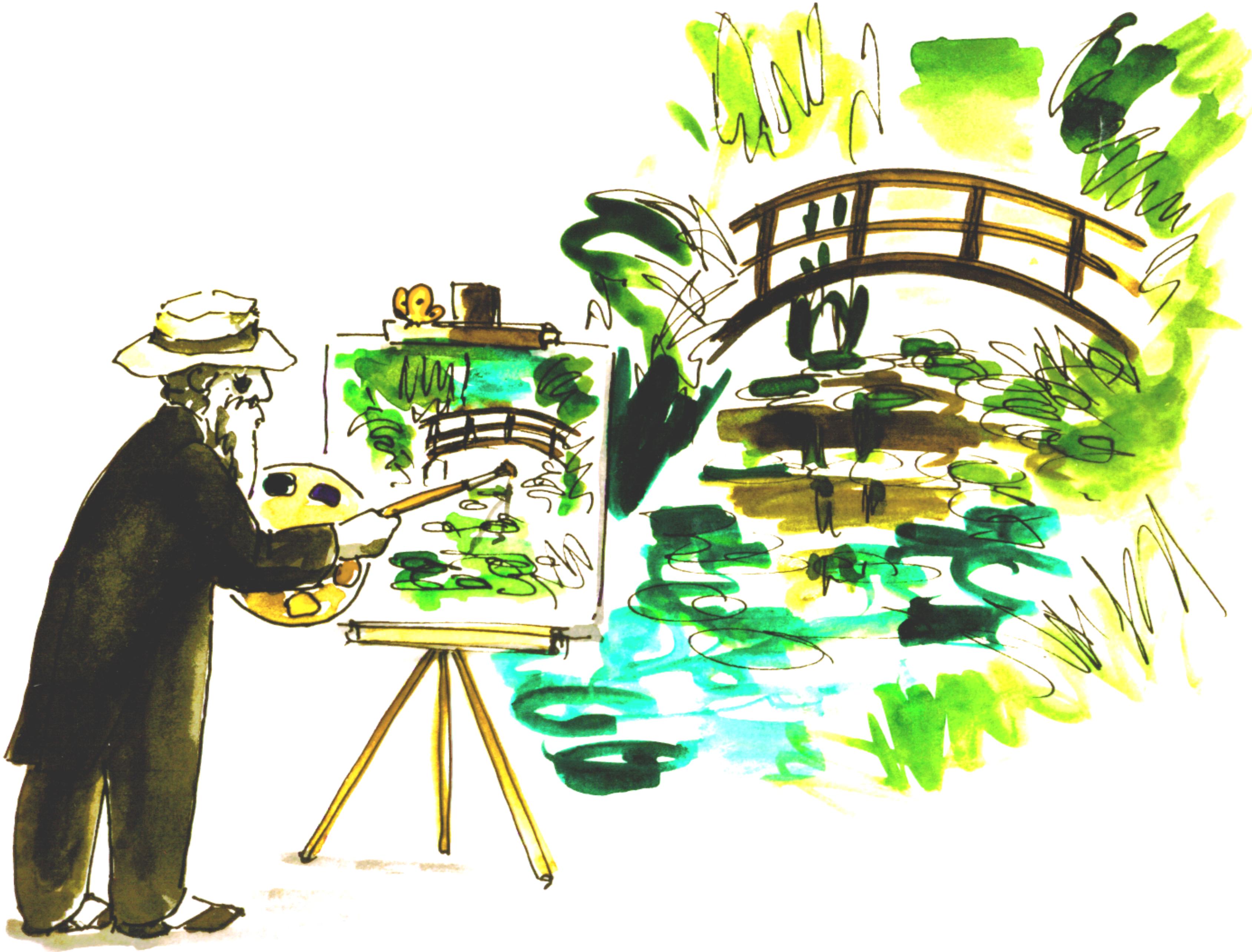
Systems thinking

Systems thinking embraces complexity, recognises connectedness, and encourages us to take a holistic view.

The basis of systems thinking is the identification of ***feedback loops***, as depicted on a ***causal loop diagram***.

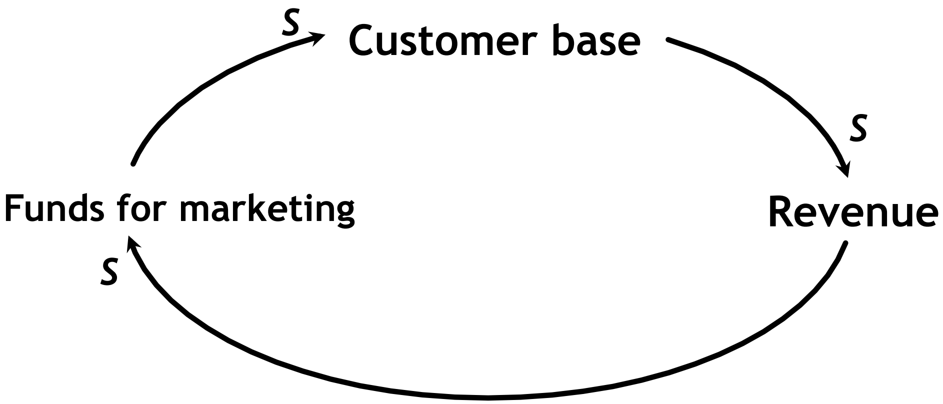
The representation of reality in terms of interconnected feedback loops vividly captures a holistic view, for it denies statements of unilateral causality such ‘A causes B’. Such a statement must be incomplete, for although A might well be the immediate or obvious cause of B, the feedback loop which links B eventually back to A implies that B in turn influences A. A and B are mutually interconnected, and influence each other. Furthermore, if a feedback loop is broken in any way, this action destroys the connectedness, and the system fails – that’s why pouring a glass of wine whilst wearing a blindfold is liable to lead to a mess.

Loops are therefore a natural way of describing complex, interconnected systems.



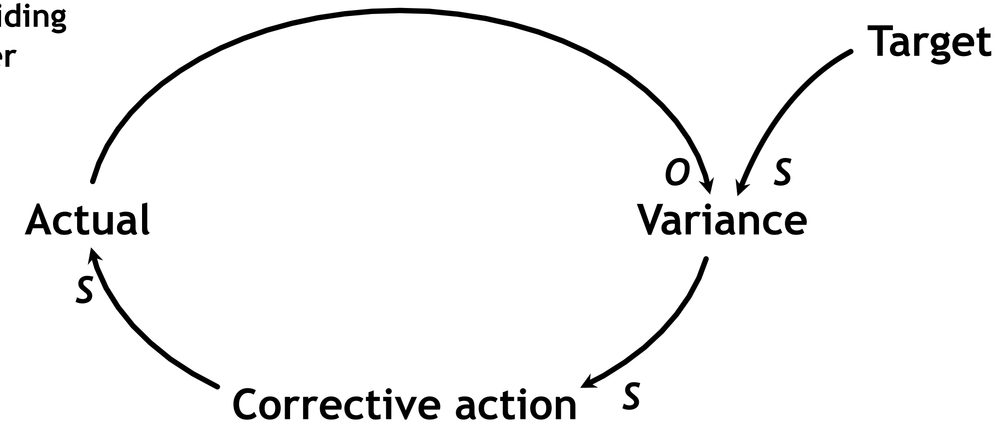
Drawing causal loop diagrams

- Choose the variable of predominant interest - for example, profit, market share, staff motivation, or whatever.
- Then ask the question “What are the key drivers influencing this?”, and list them.
- To simplify a long list, ask “Which of these are the most important?”. This ranking may enable you to eliminate some items. Also, see if a number of items can be grouped together as a wider category - for example, ‘pay’ and ‘benefits’ might be brought together as ‘remuneration’.
- Show the causality by linking the drivers to the original variable by an arrow.
- If an increase in a driver causes an increase in the original variable, put an ***S*** by the head of the arrow (for ***s***ame).
- If an increase in a driver causes an decrease in the original variable, put an ***O*** by the head of the arrow (for ***o***pposite).
- Continue backwards around the diagram until the all loops are completed.



A reinforcing loop

The *customer base* generates *revenue*, providing *funds for marketing*, so attracting a larger *customer base*.



A balancing loop

Any *variance* between the *actual* and the *target* leads to *corrective action*, bringing the *actual* closer towards the *target*.

Feedback loops are of only two types

Individual feedback loops are of only two types:-

- *reinforcing*, or *positive*
- *balancing*, or *negative*.

Reinforcing loops show exponential growth or decline - the same structure can act as both a virtuous and a vicious circle, depending on how the system starts.

Reinforcing loops have an even number of *O*-links (with zero counting as an even number).

Balancing loops oscillate, or modify the rate of growth (or decline) of an associated reinforcing loop, or tend towards a stable state, often as determined by an external goal or target. The goal or target is usually shown on a causal loop diagram as a ‘dangle’.

Balancing loops have an odd number of *O*–links.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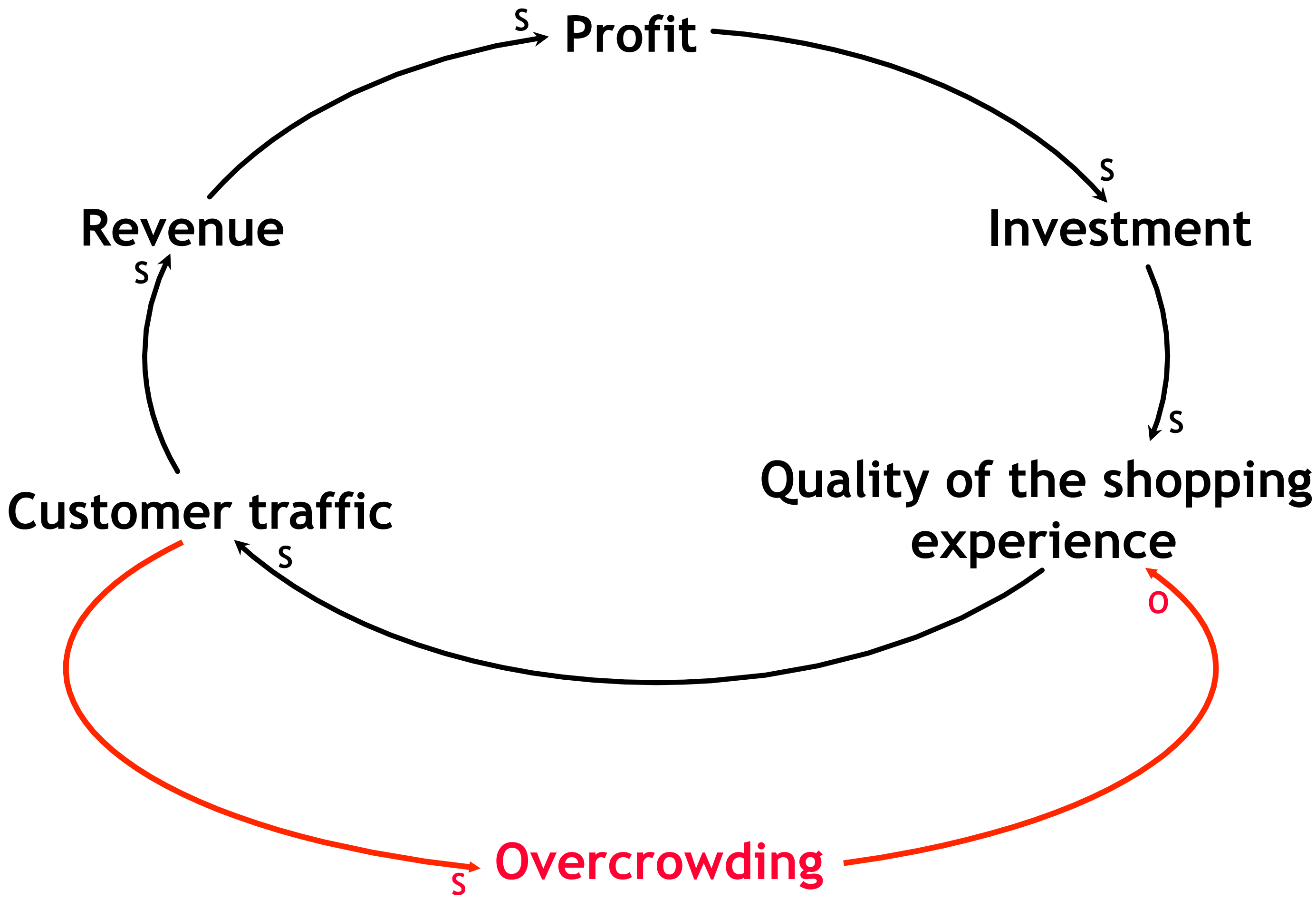
Real systems

Real systems are composed of networks of interconnected reinforcing and balancing loops.

Although the time-dependent behaviour of any individual reinforcing or balancing loop can usually be grasped quite readily, the overall behaviour of a network of interconnected loops can be inferred only in the simplest cases.

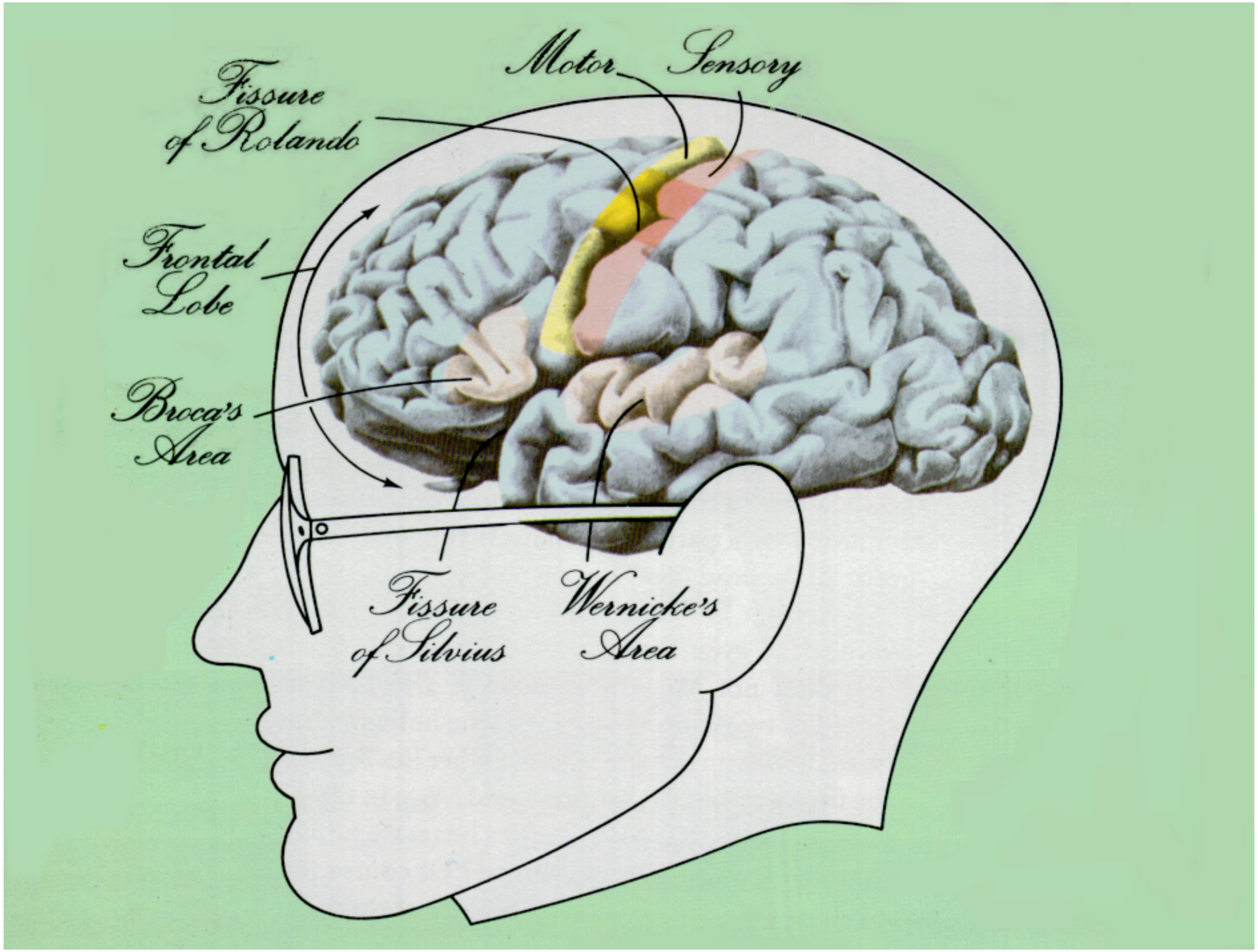
To help us understand the dynamic complexity of real systems, in addition to studying the causal loop diagrams, we can build computer models. The modelling aspect of systems thinking is known as ***system dynamics***.

A retail causal loop diagram



An example - retailing

- The diagram shows a simple causal loop diagram illustrating one aspect of the growth of a retail business.
- Our starting point is our goal of growing ***profit***. This is driven primarily by ***revenue***.
- The next step is to determine the key drivers of revenue. There are many possible answers to this, but let's suppose that the management team agree on ***customer traffic***, which in turn is driven by the ***quality of the shopping experience***.
- This in turn is driven by the level of *investment*, which itself is driven from ***profit***, so completing a reinforcing loop.
- The volume of ***customer traffic***, however, can cause ***overcrowding***, which feeds back to diminish the ***quality of the shopping experience***, so introducing a second, balancing loop, which counteracts the growth dynamic of the reinforcing loop.


Motor
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Fissure
of Silvius
Wernicke's
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Mental models

When drawing a causal loop diagram, the key question to ask is “what drives…?”

Sometimes, the answer is a matter of accounting definition (*revenue* drives *profit* according to the rule ‘profit equals revenue multiplied by a margin’); sometimes the answer is a matter of data (‘*overcrowding* occurs when there are more than so-many people in the shop at any one time’). Very often, however, the answer is a matter of belief - for example, the assertion that *customer traffic* is driven by the *quality of the shopping experience*.

These beliefs - or **mental models** - are fundamental to our personal opinions, and have a major influence on the way we behave. The process of defining causal loop diagrams inevitably encourages people to articulate their mental models. Different people will have different mental models (“I think that price is a stronger driver of customer traffic than the quality of the shopping experience”), and the ensuing discussion is an important aspect of generating consensus and building teams.

Teamwork

What is a team?

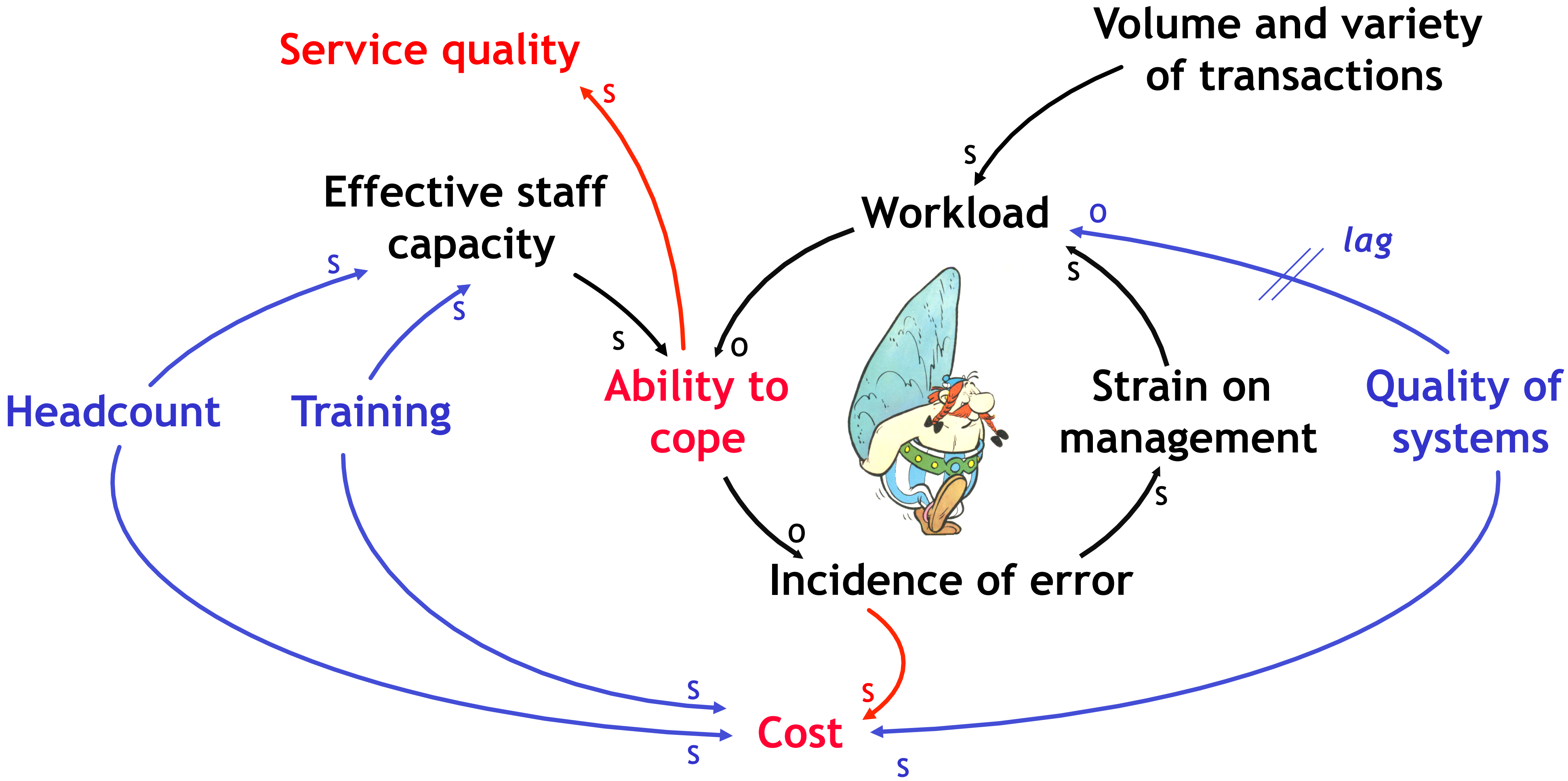
One definition is ‘a group of people who spontaneously share many mental models’ .

This definition is surprising, for it is not especially obvious. But it has great meaning.

Your mental models articulate how you see the world, and represent your fundamental beliefs not only about many business matters, but about many personal ones too. You will naturally prefer to spend time with others who see the world more or less as you do.

In everyday life, this is intuitive; in business, the process of drawing causal loop diagrams makes the articulation of mental models explicit, enabling them to be shared and discussed. This is fundamental to building high performing teams.

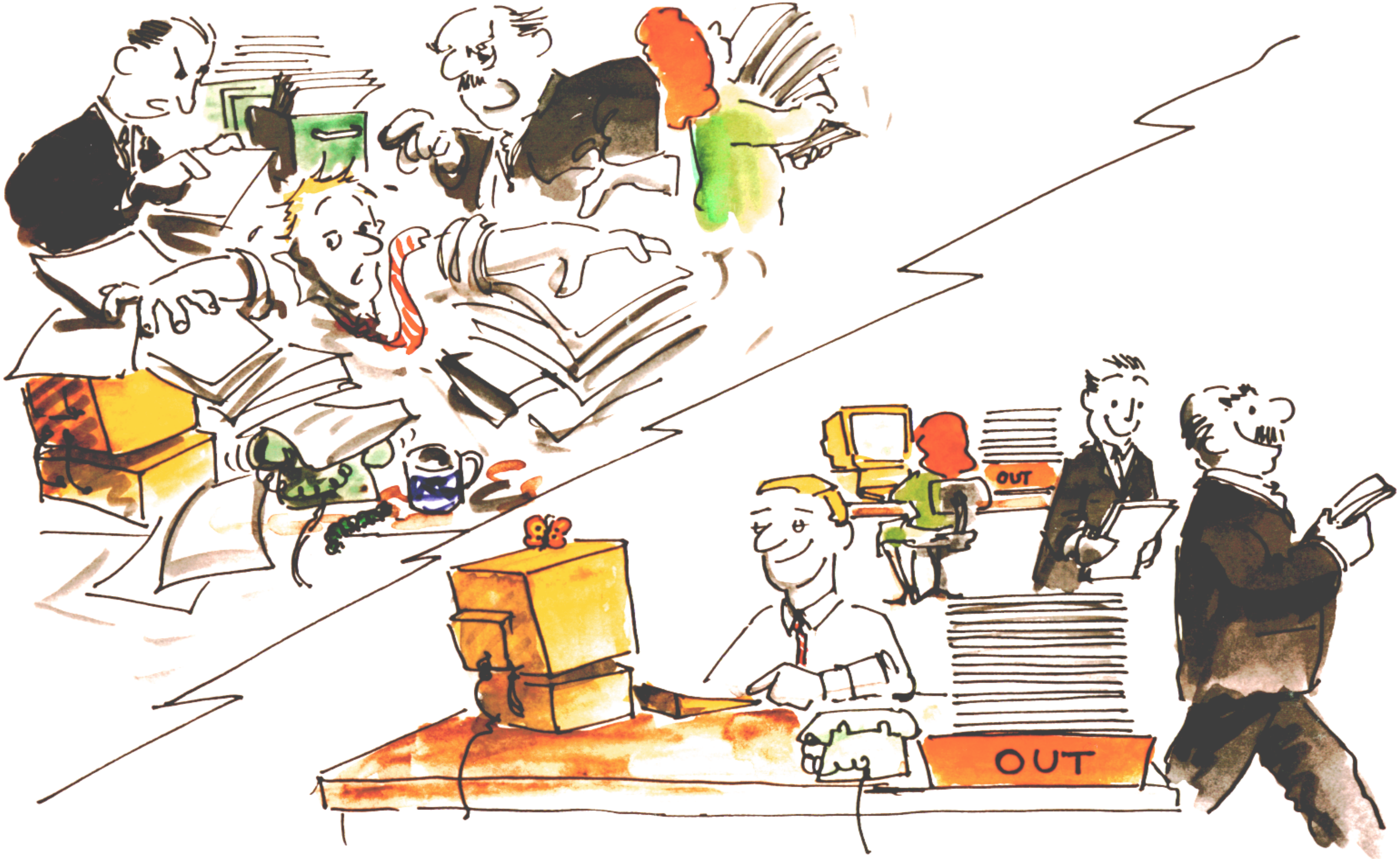
A causal loop diagram for back office processing



Items in *red* are *objectives*; those in *black* are *key variables*; those in *blue* represent *policies*.

An example - back office processing

- The key of objective of the busy back office operations manager is to maximise his or her ***ability to cope*** whilst controlling *cost*. The prime driver of the ***ability to cope*** is the ***workload***, as determined by the ***volume and variety of transactions***.
- One possible consequence of a reduction in the ***ability to cope*** - as, for example, might arise if there is a surge in transaction ***volume*** - is an increase in the ***incidence of error***, so increasing the ***strain on management***, and further diminishing the ***ability to cope***. This reinforcing loop can therefore behave as a singularly vicious circle.
- This unhappy situation may be avoided in two ways. Firstly, the higher the ***quality of systems***, the lower the ***workload*** on the operations function; secondly, the greater the ***effective clerical capacity***, the greater the ***ability to cope***. The ***effective clerical capacity*** itself is determined by the ***headcount*** and ***training***, both of which drive up ***cost***; ***costs*** are also incurred in systems development. ***Errors***, however, are also costly.
- What is the optimal level of investment in ***headcount***, *training* and ***systems*** so as to minimise the ***cost of error***, given the inevitable uncertainty in the ***volume and variety of transactions***?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Policy

The causal loop diagram for back office processing highlights some important business trade-offs and policy issues. For example, cutting back on ***headcount*** and ***training*** reduces *cost*, but it also reduces the ***ability to cope***, with the consequent possible increase in the ***incidence of error***. It could be that that cost resulting from error is far greater than the amount saved by the original cut-backs. How far can you cut back wisely?

Furthermore, the development of new ***systems*** increases ***cost*** in the short term. But in the longer term, when the systems come on stream, they can act to buffer surges in the ***volume and variety of transactions***, and so maintain a steady ***workload***. This in turn implies that the ***headcount*** required to maintain the ***ability to cope*** might be lower, since there would no longer be a need to staff up for volume surges, or to cope with 'specials'.

So, how can you best allocate investment across recruitment, training and systems development?

Causal loop diagrams are powerful aids to the balanced discussion of policy.

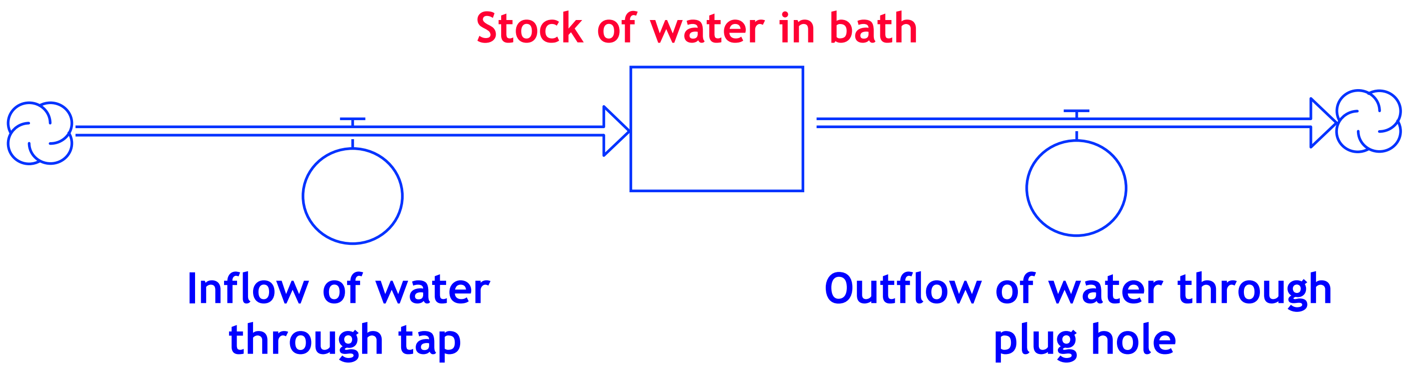
Modelling

Causal loop diagrams can also form the basis of computer simulation models, which enable you to explore how key variables evolve over time.

These models are known as ***system dynamics*** models, and use specialised software tools, such as ‘ithink’.

The structure of system dynamics models is different from spreadsheets: rather than being based on rows and columns, they are based on ***stocks*** and ***flows***.

An example of a stock and its corresponding flows



Stocks and flows

STOCKS are items that accumulate over time.
Stocks are conventionally shown as **rectangles**.

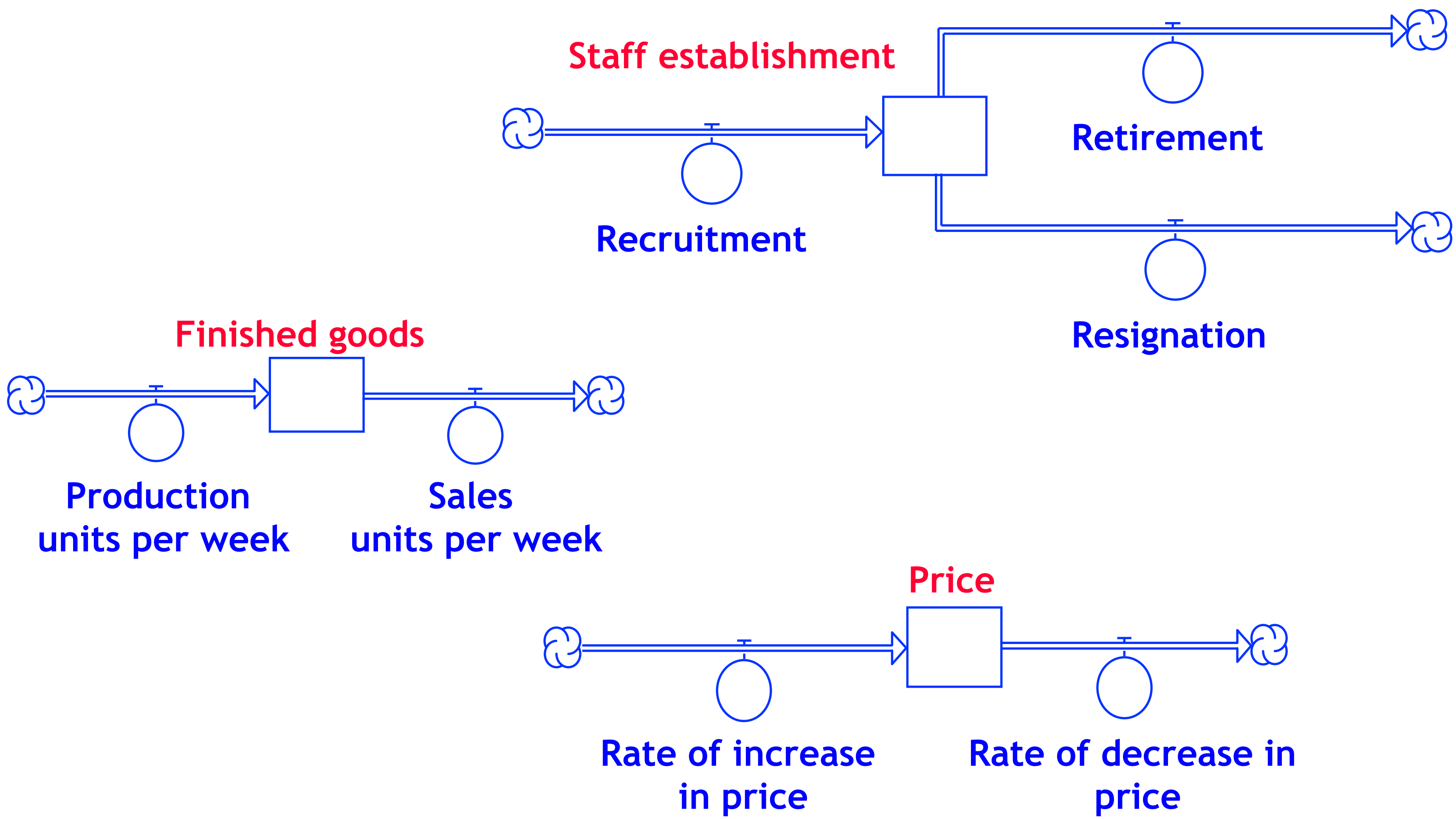
FLOWS are items that increase or decrease stocks.
Flows are conventionally shown as **pipes with taps**.

A stock may be likened to the quantity of water in a bath, as determined by net result of the flow into the bath through a tap, and the flow out through a plug hole.

If the settings of the tap and plug vary over time, the quantity of water in the bath will also vary. And if several baths are interconnected through a network of taps and plugs, the behaviour over time of the various quantities in the different baths can be quite complex.

System dynamics models trace this time-dependent behaviour, and can help tame the complexity.

Some examples of business stocks and flows

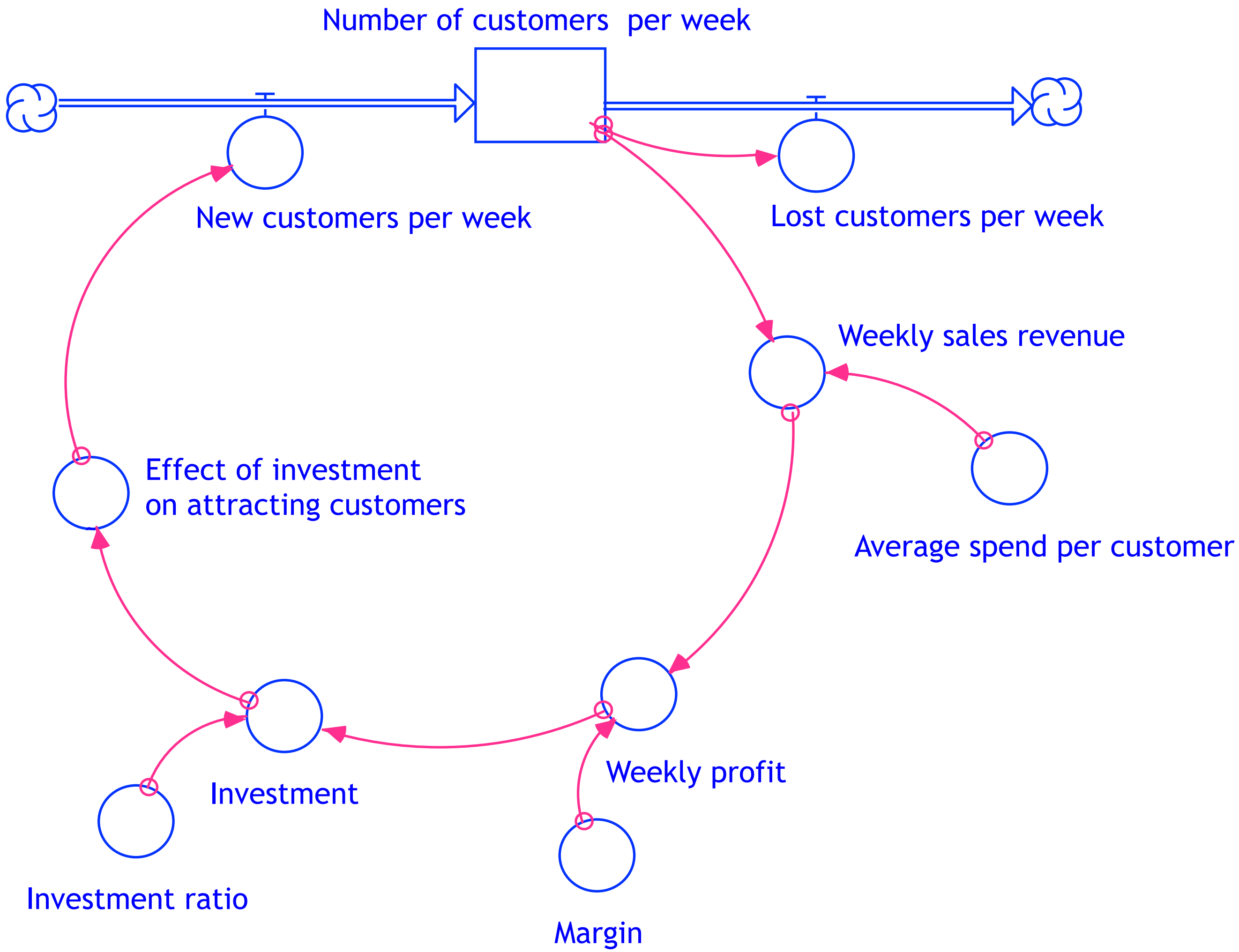


Stocks and flows in business

Some examples of business stocks and the corresponding flows are:-

STOCKS	FLOWS
Physical inventories	Deliveries; despatches
Cash	Cash flow in; cash flow out
All balance sheet items	All profit and loss items
Customer base	Rate of gaining or losing new customers
Manpower establishment	Rate of recruitment; retirement
Knowledge	Training; 'human obsolescence'
Quality	Rate of quality improvement; decline
Price	Rate of price increase; decrease

An example of a plumbing diagram



Plumbing diagrams

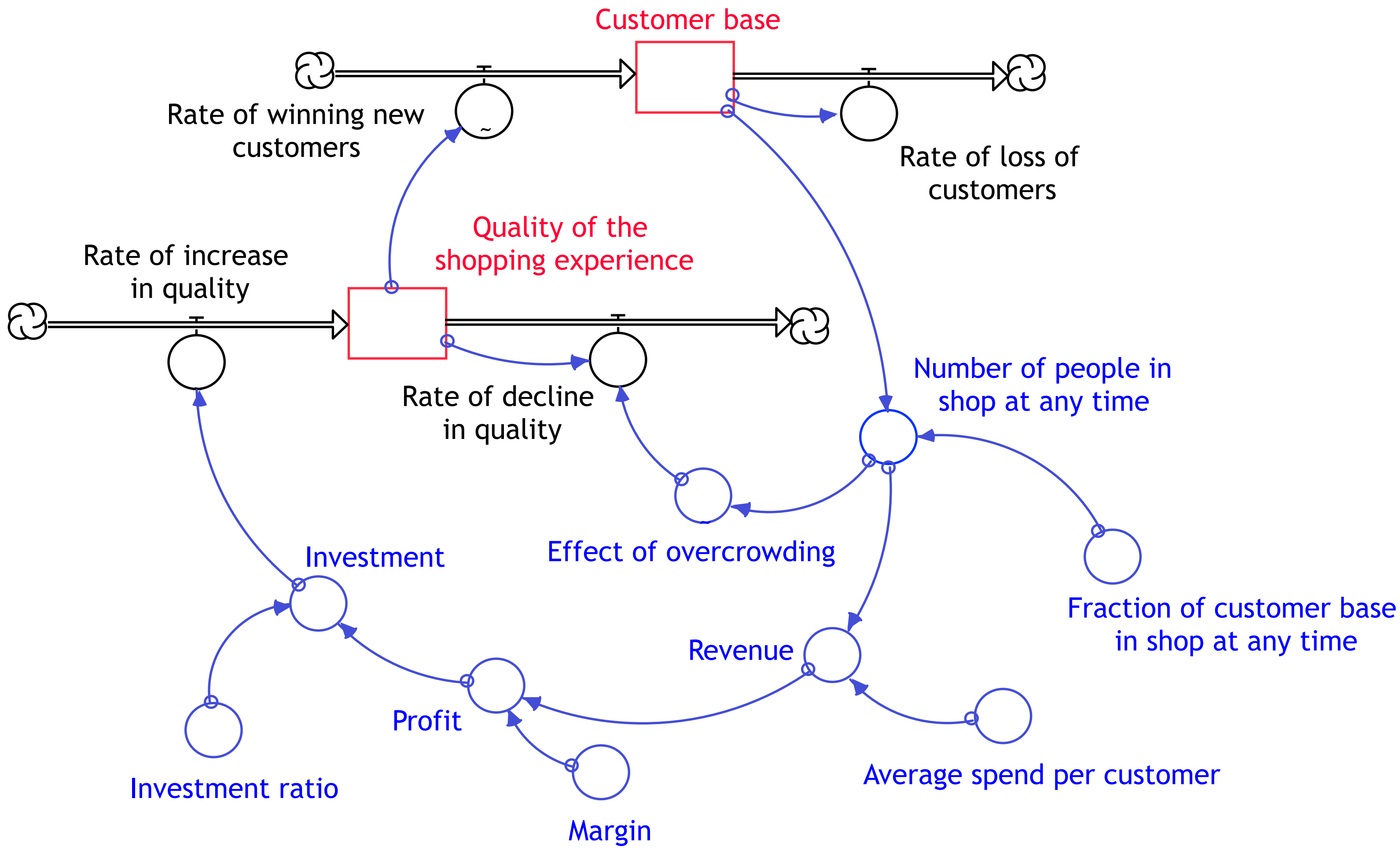
System dynamics models are conventionally represented as ***plumbing diagrams***, showing the interconnections of all the stocks and flows.

Variables not explicitly shown as stocks or flows are known as **converters**, and are represented by **circles**.

Plumbing diagrams are usually more detailed than the corresponding causal loop diagrams, for they need to show all the necessary variables.

System dynamics can also accommodate 'fuzzy' variables, such as 'the effect of investment on attracting new customers', by using graphs to capture the corresponding mental models.

A plumbing diagram for the retail causal loop



Items in *red* are *stocks*; those in *black* are *flows*; those in *blue* represent *other variables*.

A plumbing diagram for the retail causal loop

This plumbing diagram is consistent with the retail causal loop diagram discussed earlier.

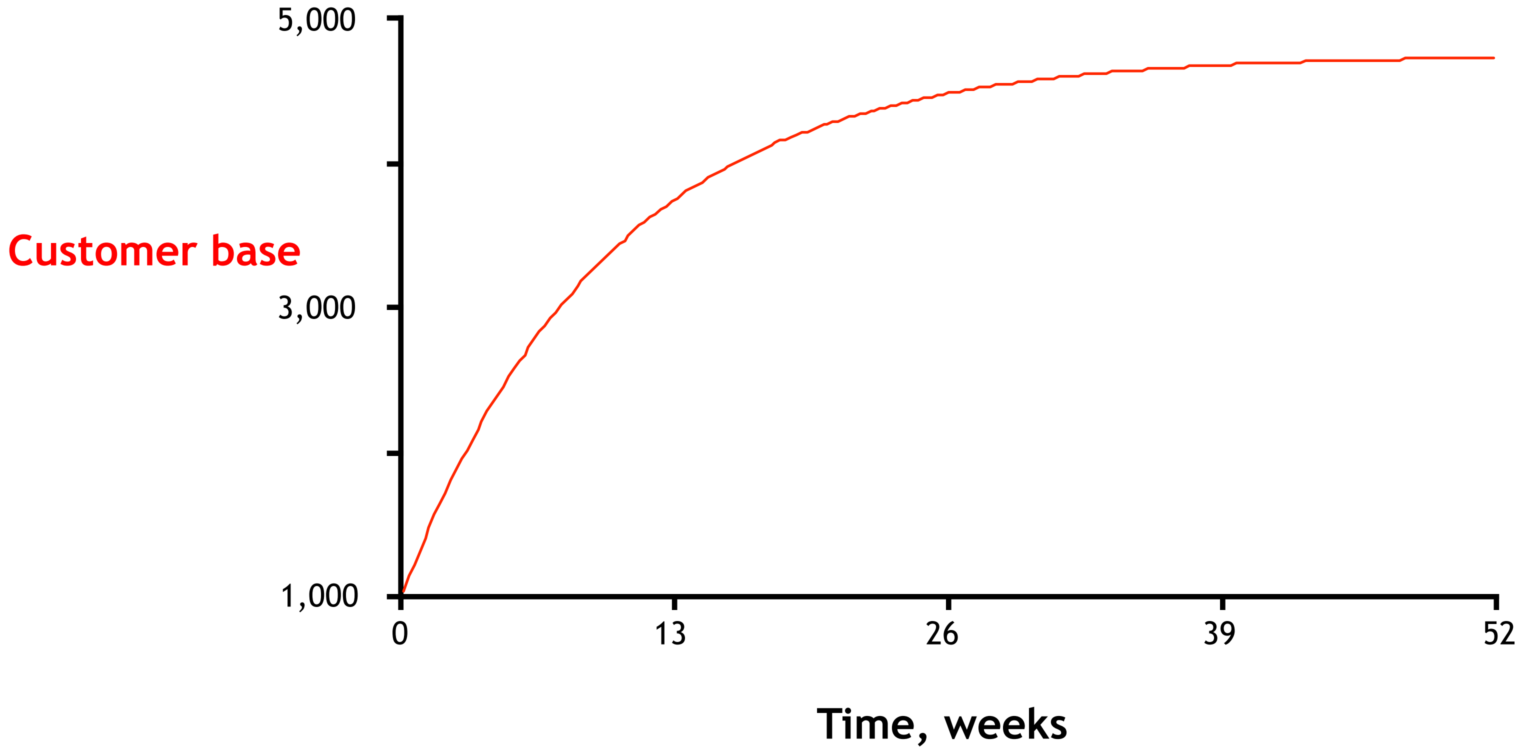
The diagram shows two key stocks: ***customer base*** and ***quality of the shopping experience***.

The reinforcing loop links ***customer base***, ***revenue***, ***profit***, ***investment*** and ***quality of the shopping experience***. A number of other parameters are also shown in order to specify the required calculations: for example, ***profit*** is computed as ***revenue*** multiplied by ***margin***.

The balancing loop links ***customer base*** through the ***number of customers in the shop at any time*** and the ***effect of overcrowding*** back to the ***rate of decline in quality***.

The diagram uses graph functions to capture the effects of investment on enhancing quality, of quality on attracting customers, and of overcrowding on reducing quality.

One behaviour of the customer base over time



One behaviour of the customer base over time

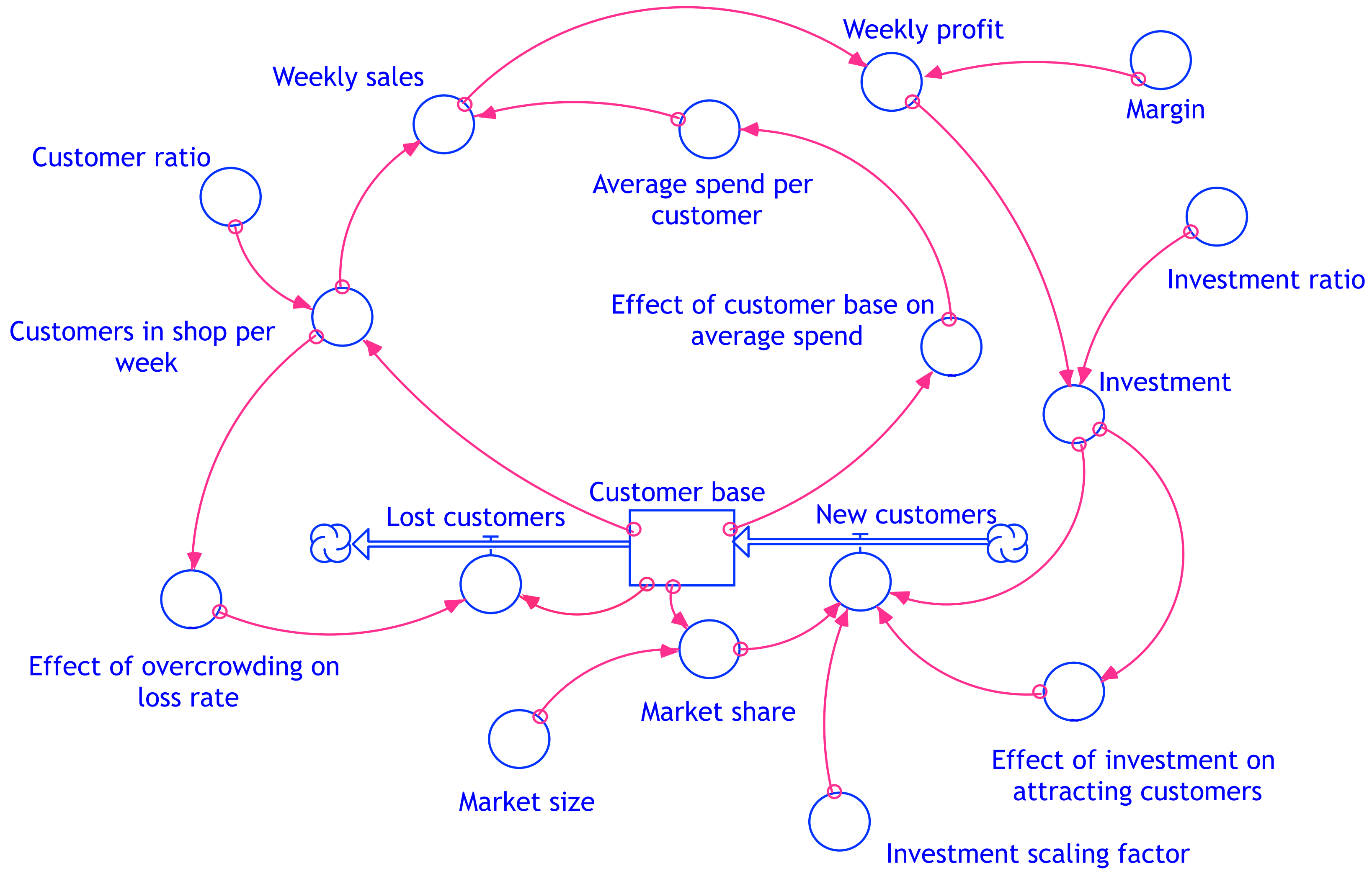
The plumbing diagram can be drawn directly on the screen using the software product ‘ithink’.

‘ithink’ then prompts you to specify the required calculation rules, such as ***revenue*** equals ***profit*** multiplied by ***margin***. ‘ithink’ also enables you to draw any required graph functions.

The model then tracks the evolution of all the variables over time, generating graphs such as the one shown on the opposite page.

This shows that, for the parameters chosen, the customer base rises to a steady state, with the balancing loop cancelling out the growth dynamic of the reinforcing loop. The choice of other numerical or graphical parameters can result in other behaviours, such as continued growth, or boom followed by bust.

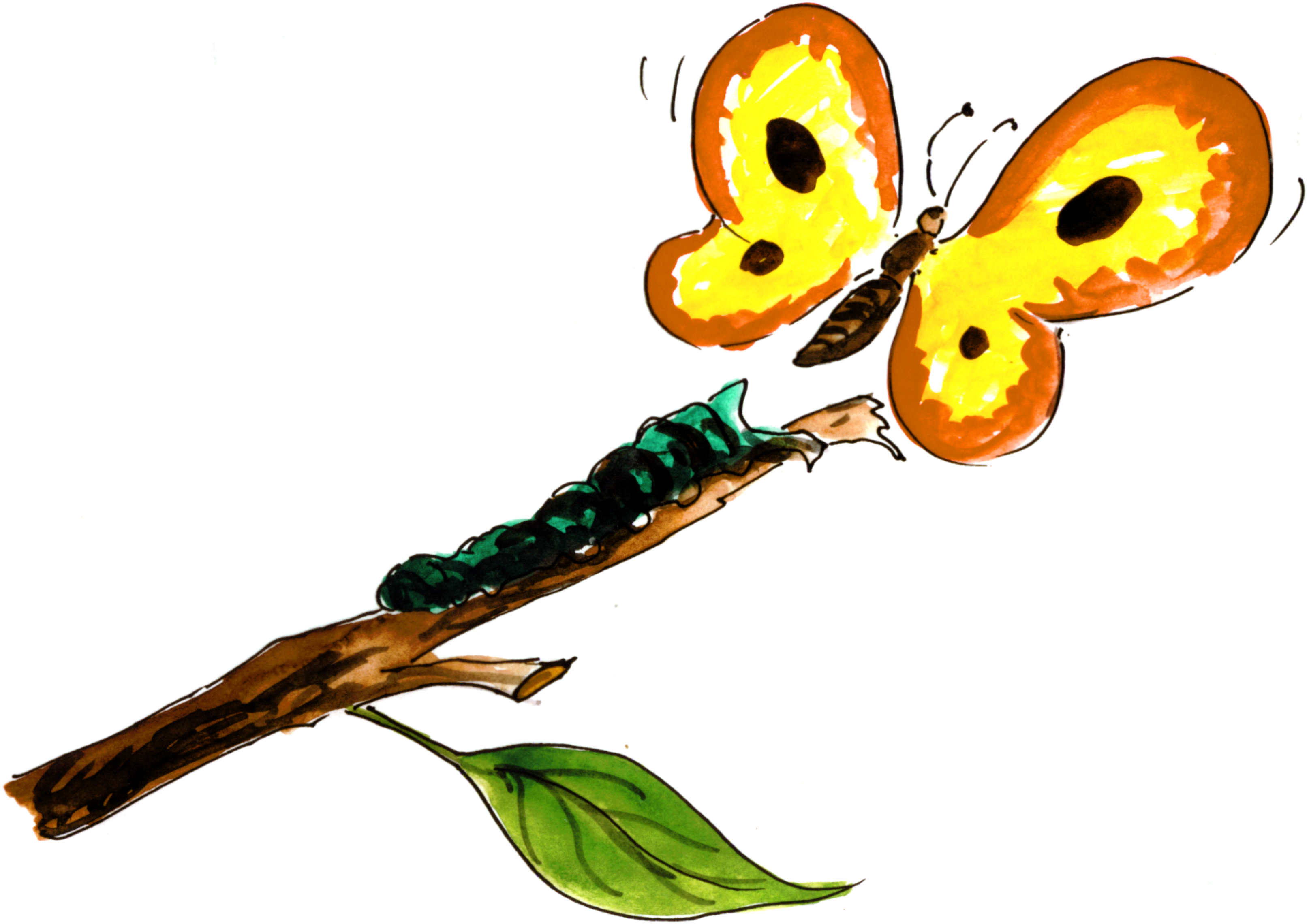
A more complex retail causal loop diagram



Models can become quite complex...

The plumbing diagram for the original retail example was relatively simple, as was the corresponding causal loop diagram. Although some models can be both relatively simple and insightful, many models quickly become quite complex - as the accompanying diagram illustrates. Even so, models will always be composed of interconnected balancing and reinforcing loops, forming powerful representations of a complex reality.

Very few people, however, can anticipate the dynamic behaviour - the way in which selected key variables evolve over time once all the interconnections are taken into account - of a complex model. Simulation modelling is therefore invaluable as a 'laboratory' to explore how the system behaves under a variety of selected assumptions.



A final thought

Business objectives are usually expressed in terms of the simultaneous optimisation of a portfolio of stocks, and the maintenance of that optimum over time.

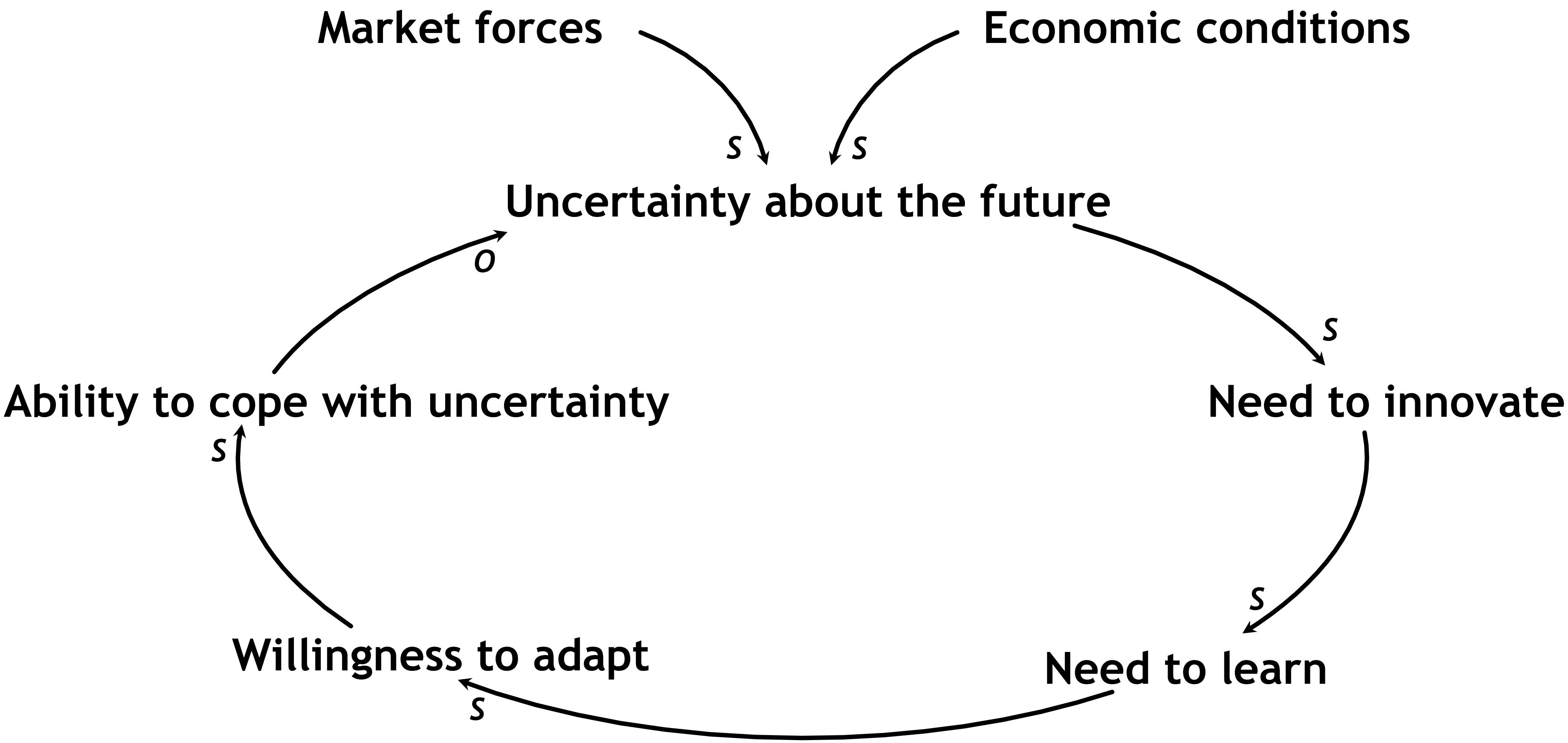
No manager, however, can influence stocks directly: managers can only influence the flows.

The problem of management is therefore analogous to optimising the quantities of water in a series of interconnected baths, when the only actions a manager can take are to set the taps and the plugs.

That's why managing is difficult.

And that's why systems thinking and system dynamics can help.

A blueprint for the twenty-first century



For further reading...

Seeing the Forest for the Trees – A manager's guide to applying systems thinking, by Dennis Sherwood, published by Nicholas Brealey Publishing, London, 2002.

A comprehensive and accessible introduction to the subject, also published in German by John Wiley under the title *Den Wald for lauter Bäumen sehen*.

Industrial Dynamics, by Jay Forrester, published by the MIT Press, Cambridge, Massachusetts, 1961.

The seminal text on system dynamics and systems thinking, which still reads freshly today.

The Fifth Discipline, by Peter Senge, published by Doubleday, New York, 1990.

A persuasive and articulate exposition of the role of systems thinking in management, alongside the four other key disciplines of 'personal mastery', 'mental models', 'shared vision' and 'team learning'.

Business Dynamics: Systems Thinking and Modeling for a Complex World by John Sterman, published by Irwin/McGraw-Hill, Boston, 2000.

The current standard text, written by MIT's leading professor.

Strategic Modelling and Business Dynamics, by John Morecroft, published by John Wiley & Sons Ltd. Chichester. 2007.

A lively and well+informed exposition written by one of the UK's most experienced modellers.

Idea generation, evaluation and development

Making innovation happen

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Strategy development and scenario planning

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Building ultimate competitive advantage

Building high-performing teams

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Training and knowledge transfer

Conferences

Business and market modelling