Managing Complexity in Projects and Programmes

Bridget Rosewell

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Introduction

This chapter looks at the challenge of managing complexity. I concentrate on identifying the forms that complexity may take and in doing so how to manage, control our perhaps outwit it. I introduce a taxonomy which can be used and a set of potential reactions to its identification.

I use examples of projects and programmes both in infrastructure and in macroeconomics to illustrate these points.

What is complexity?

The word complex is often used loosely and it is important to distinguish the complex from the complicated. A complex project or programme is not simply one which has many elements. So long as the many elements can be organised and controlled in a linear or flow chart picture, there may be many complications and dependencies but it will not be complex. This does not of course mean that a complicated project is easy, or that controlling it does not require skill and much planning. There can be pinch points and single points of failure in a complicated project or process. Indeed mapping a complicated process in order to control it may be difficult and challenging. The development of LEAN techniques has been all about improving these mappings so that control can be better understood and linkages improved. However, this is still not complexity.

Complexity is introduced in creating dynamics and feedback interdependencies for a project. There are several variants of this. One example is that of the sand pile. Each grain of sand, delivered in the same way to the top of the pile, impacts on all the others. Sometimes it creates a small trickle of impacts, but sometimes these impacts gather force and the whole pile shifts shape. A small change has a large impact which cascades through the system in an unpredictable way.

This is an example of an unpredictable feedthrough which depends on innumerable relationships and an element of randomness. The fashion industry provides good examples, where one product can take off, but another fail. No matter what effort is put into forecasting, some films are unexpected successes and others fail very expensively. The dynamics of impact are affected by exactly who talks to who and when, to either prevent or to amplify impact.

Feedbacks can exhibit similar characteristics. An example to think about is car travel. I might brake slightly sharply having got too close to the car in front. Others behind me also have to brake more sharply as a result but no incident occurs. However, as the braking percolates back through the system a driver changing lanes suddenly finds that the expected space is no longer there and an accident occurs. The proximate cause of this is the driver changing lanes but the original event is my somewhat sharp braking many hundreds of yards ahead. I and those around me are completely unaware of events later in time but further back in the system.

Modelling such feedbacks and including them in the control process - what we might call linearisation - is impossible. The modelling required and the detail are so large as to make the model the same size as the system modelled. In both the examples here, the elements that would be required and the computing power would be immense. Our inability to describe and predict every element in the sand pile or every car on the road leads to probabilistic outcomes, or indeed uncertainty where outcomes might be unknown.

For practical purposes not all such effects might worry us. If I’m making a film, I might know that some research[[1]](#footnote-1) shows that teams which include some people who know each other well and have worked together before but some who have not increases the likelihood of innovation. However, since this doesn’t really help me know whether the film will succeed I am likely to ignore this for all practical purposes.

In order to consider more effectively how project management is affected by complexity and what, if anything, can be done about it, it is useful to distinguish between the three elements described above. Although they interlink the response to each is different.

First, dynamics. Identifying amplifying tendencies through small individual impacts on numerous agents or activities is one type of complexity which will differ from a complicated system. This is because the dynamics involves many impacts rather than a relatively small number which can be incorporated into the model or the plan.

Second, feedbacks. Complexity is introduced with feedbacks which are hard to pin down. Such feedbacks are indirect, and their strength can vary from occasion to occasion so that not all iterations of the model produce the same result.

Third, unpredictability. In fact both the dynamics and feedback mechanisms described above will generate difficulty in forecasting, because of uncertainties in how the dynamics and feedbacks evolve in any given case. However, a third element in unpredictability is sheer uncertainty and randomness. Either it is impossible to know what the correct model is and how linkages between elements of the project or programme should be defined, or there may be known elements of random impact from the weather for example, or behavioural elements which cannot be described in any other way.

The next section of this chapter look at examples of each of these phenomena and the challenges that they have presented to managing and planning.

Managing and Planning

I want to consider project and programme management in their widest sense. In the first instance, much of management is about policy and programme development and planning for implementation. The decision to undertake a project is one of key elements in the management of a project or programme and reflects the analysis of costs, benefits, risks and probabilities. Sometimes, perhaps more often in the public sector, planning and policy is undertaken without reference to implementation and delivery. However, this by itself does not create complexity, though it might create failed expectations!

Programme and project analysis is done in many ways in both public and private projects and uses a range of criteria. Criteria can include environmental impacts or merely financial benefits. Quite often, analysis may be quite vague and decisions may even override more formal criteria. It is notorious that the decision to invest in the extension to the Jubilee Line was made in spite of the fact that formal cost benefit analysis showed, on the chosen criteria, a ratio of less than one. The family decision to move house is likely to require a variety of considerations in order to make a decision. These will be emotional as much as anything else and not everyone will set out a list of pros and cons. In making a decision, elements of possibility, of impact and so on will all be taken into account, however implicitly.

Even in a formal analysis, both costs and benefits are subject to uncertainty. The UK Treasury, in its Green Book[[2]](#footnote-2), refers to ‘Optimism Bias’ as the tendency of all project planners, whether in the public or private sectors, to underestimate costs. Perhaps surprisingly, the publication does not mention a common procedure to present estimates with probabilities attached to them. A ‘p80’ project is estimated to have an 80% chance of coming in on budget, while p50 is much less certain. These estimates are meant to imply that there is a 50 per cent chance of coming in user budget as well as over budget but it is noteworthy that p80 budgets are almost always higher.

The certainty around cost also implies some certainty around delivery mechanisms and therefore how implementation will be managed. Without a programme plan, quotations cannot be prepared, nor risks identified. The point at which design turns into a delivery plan is often the midpoint in a project and the point at which the p80 estimate is reached.

Project implementation and delivery is also where the planned benefits are to be found. Identification and measurement of these are essential to judging success but are harder to identify, further in the future, and subject to impact from external factors. A key element in any programme or project is the boundary condition. What is in or outside the plan will also determine what is thought about in considering either the costs or the benefits. Missing a significant factor can introduce complexity simply by omission.

In principle, it is possible to imagine a plan which has taken into account all possible factors. In practice, this is impossible to imagine. Even if all the major impacts are taken into account, surprise is always possible. An example is consideration of ground conditions. Even where trial trenches have been dug, geo-technical surveys done, the real dig is different and can throw up variability outside that expected. This kind of surprise is impossible to predict and hard to allow for in a plan. What can be done is to know that surprise is possible and what might flow from such surprise.

Consideration of scenarios can be as important as thinking about probability. A scenario can identify the high impact low probability event which can scupper chances of project success, and which probability analysis might miss. Scenarios can also help in thinking about dynamics which could ‘take off’.

Dynamics

Economists are fond of comparative statics. Let us change one thing - for example build a road - and assume the rest of the world behaves in the same way as it did before. Then a model describing the pre-existing situation can also describe the impact of the new road and a subsequent equilibrium outcome. Such models are still in general use to model the impact of changing interest rates, for example. It has, however, slowly become apparent that the rest of the world does not remain the same and that the reactions over time of other agents in the economy can undermine the static result. It was a surprise when new roads filled up and became as congested as the old ones. In a static world, there would be the same number of trips and so they would becomes faster and the roads less busy.

In both transport and indeed in macroeconomics, these surprises have led to the addition of dynamics. Transport systems are now mandated to think about Land Use Transport Interaction models,[[3]](#footnote-3) where the introduction of a transport improvement leads to new trips, and new activities over time. This adds to the consideration of how a project should be managed, and indeed the priority to be placed on projects.

LUTI models are not really dynamic in the complex sense. It is true that they add a layer of additional factors which could affect the outcome, and sometimes they include an appreciation of the time it might take for the impact to take hold. So in the road example, would the new road fill up quickly, or would there be a long time of lower congestion before new trips are created? If reduction of congestion was the object of the exercise, then that might be acceptable. If the growth potential occurs quickly, then this would only be all right if the objective is economic growth! But the source of economic growth implies dynamics of a rather different sort. LUTI models rest on an unchanging description of the economy, where trade and output are generated within the existing parameters. But growth dynamics might be quite different.

A potential narrative is as follows: the new road enables me to reach a new market, raise sales and increase employment. My new employees bring new ideas to my enterprise and encourage me to create new product ranges. Or perhaps they give me more confidence to try something new. This will not be captured in models based on describing the world as it is. And yet this kind of thing is integral to the way that productivity advances. This kind of dynamic is indirect and depends on multiple small impacts, hard to integrate into the planning model.

A different sort of dynamic is apparent in the continuing debate over the implementation of High Speed Rail in the UK. The first case made for this railway was a standard static case. People made trips, and quicker trips would save time and this could be valued. The planning of the project was focused on building a railway which save the maximum amount of time and a key criterion was that it had to run at 400 kilometres an hour. The result of this case was opprobrium. Opponents scoffed that the cost of saving 20 minutes on the trip to Birmingham was far in excess of any real economic benefit.

Subsequent debate has shown that the project is about far more than this. Saving 20 minutes to Birmingham is only a small part of what is needed. Not only is the existing capacity insufficient to meet demand, but it is time savings to Manchester, to Leeds, Liverpool and Scotland that would actually be significant. Improving inter-city linkages is about market access, improving trade conditions and replacing air travel. Speed is only one criterion.

For many north of the Midlands, High Speed Rail is about a dynamic which changes their attractiveness to investment and their ability to be successful cities. The interesting interaction here is between the dynamic of the objective and the dynamic of the planning process. Planning was based on a speed criterion which is only part of the objective from the cities’ point of view. A criterion of say, 350kph, would have produced different design standards and probably a different railway, with possibly fewer subsequent rows.

A focus on economic opportunity would also generate different financial options and development criteria for stations, for the timing of station development. An appreciation of a different dynamics would produce a different dynamic in planning, in procurement and in delivery. Slowly we are moving in this direction as the project develops, but a lot of time has been wasted. The National Audit Office[[4]](#footnote-4), in its report on HS2 planning, reported that it was impossible to evaluate the value for money of the project because its objectives were so confused. For many, they remain so.

Getting some feedbacks into the planning system has, interestingly, proved easier - at least up to a point.

Feedbacks

The process of agglomeration is a feedback loop. More people working in the centre of the city enable a variety of markets to work better. The labour market has more opportunities so that people can choose the job that suits them more easily and employers can find workers who can do the job. New ideas can get traction more easily as like-minded people meet. New companies can find a niche which gets them started. Competition drives down prices. This process was first described in the nineteenth century by one of the fathers of economics, Alfred Marshall, which perhaps explains why it was easier to get it accepted in planning. He described this process in the cotton centres of Manchester, rather than for London.

This loop implies that additional people working in this agglomeration will be more productive than they could be elsewhere and moreover they will affect, even by a small amount, the productivity of the existing workers. Even though the feedback process is difficult to model, the results are observable. City centres have higher productivity and higher wages. This is not just a matter of high productivity sectors, it applies across the board, to sandwich makers as well as to financial analysts.

Marshall had never heard of emergence, but this is an example. The process of agglomeration creates an emergent phenomenon where the whole is greater than the sum of its parts. The interdependence of behaviours creates a city.

The case for a new railway across London - Crossrail - depended on the description of this feedback and an analysis which showed that the existing system faced gridlock without new capacity. Removing the constraint would enable the feedback effect to continue. This meant that the railway had to be able to deliver to parts of the city where growth potential existed and buildings could emerge. Connections for the growth area of Docklands, as well as for the City of London, were a key part of the project.

The design, the location of stations, and the financial arrangements were all affected by this identification of objectives. The case for Crossrail rested on the identification of the feedbacks behind the process of agglomeration. The final report[[5]](#footnote-5) which was used to buttress the case with stakeholder interests compared the standard static approach to one which incorporated feedbacks and tried to consider the time over which impacts might emerge. The benefit case used was actually well below the maximum impact possible, since the scale of benefits possible was so large as to be thought scary. The imagination really to see the long term benefits from long term investment - and after all railways last a long time - is difficult to achieve.

Moreover the budget for large scale projects is also scary. The scope for something to go wrong is large and the risk to reputations in making a wrong decision challenging. It is always easier to do nothing, and this of course feeds back onto others’ willingness to make decisions. The decision to build Crossrail had to be constructed across many stakeholders so that everyone was complicit in the decision and had a stake in making it work. The project itself is of course itself complicated, being large and building across London. It is, however, not necessarily complex. Reducing complexity is important in project delivery so that something going wrong in one part of the project does not infect others.

In the case of Crossrail, there are separate pieces of the project, run separately, and only needing to join up at a late stage. Reducing cross-infection is a key element in bringing a project down from complex to ‘merely’ complicated. Minimising hand-offs and understanding how one project can affect another is crucial. To deliver a new station requires not only supplies, but also skills such as the drivers for supply trains, the correct wagons, loaded correctly, tracklayers, ballast, tamping machines, and signallers to block other lines. All of these have to be booked and in place. But even then, staff shortages, or the impact of other projects running late can create a knock-on effect which can mean over-runs or failure to deliver. A lack of resilience to shocks can shift a project from complicated to complex in one fell swoop.

This is one element in the creation of unpredictability which very much depends on robustness and resilience, so that surprise can be avoided or managed.

Section 5 - Unpredictability

The financial crisis which emerged in 2008/9 was apparently unexpected. The system turned out to lack resilience in the face of a crisis, and to failed to build in any firebreaks. In addition, in many quarters the crisis was entirely unexpected. Indeed an element in a crisis is often that it is unexpected and unplanned for.

In a way, this is not at all surprising. If something is expected, it is planned for, mitigation is put in place and things do not go wrong, or do not go disastrously wrong. For example, in the years before the financial crisis it became commonplace in mortgage banks and building societies to use securitisation to move assets off the balance sheet and make room for new business. Securitisation brings investors in to take a slice of the assets, freeing up the balance sheet and giving investors with different risk parameters opportunity to make the investments they wish to. Although this process went badly wrong in the event, it is not wrong in principle and should be a normal part of business. When the crisis hit, however, it became clear that risk in securitisation vehicles had not been properly assessed or understood. The portfolios were not capable of sustaining the slice and dice that had been put into them and the market closed completely.

At the time I sat on the board of an institution that used these vehicles. We didn’t need to panic because we had considered what we should do in this eventuality. Although it had been considered a low probability, the consequence could be severe. Programmes were therefore in place to stop doing new business, although much of this had already been closed down on risk grounds, and backup lines of finance were already in place to deal with this risk. Crisis, what crisis?

But there were high consequence risks that we had not considered and did not have a defence ready for. As distrust spread through the market, normal interbank lending also stopped. Such lending is part of cash management and was particularly crucial to mutual societies without recourse to equity funding. Such market closure was unprecedented in 200 years. We missed it. It is no consolation to realise everyone else did too. Moreover in looking at the biggest problems of cash management and securitisation, smaller issues tended to get lost. Some of those became bigger in the future. The ability to focus but not lose sight of the total range of issues is hard to achieve.

Small changes with large potential dynamic effects, feedback loops with accelerating force, and randomness can all create forces which are hard to identify in advance. To go back to the sandpile example, how much resource should one allocate to defence against the possibility to the sandpile collapse?

It’s not hard to insure against a low probability event, but if such an event actually happens, the insurance may turn out to be useless. Exactly that happened in the financial crisis. Because the event - credit default - was considered to be highly unlikely the insurance premium was low and the insurance company felt able to take on lots of such risks. In addition to low likelihood, the credit defaults were considered individually, not collectively. So credit default swaps seemed a good bet. But once some of these insurances were needed, there was contagion and the resources necessary to cover the swaps turned out to be ephemeral, as insurance after insurance failed.

No firebreaks between individual elements existed because the risks were considered to be low probability and therefore manageable. The potential for contagion - the sandpile effect - was not considered, and neither was the feedback loop of peoples’ expectations which then closed markets altogether. Even if models predicted the catastrophic outcome, they would not do so with certainty.

The role of randomness provides a further twist. Random could mean a factor we haven’t managed to incorporate and therefore seems to come from outside. Or it could be genuine variability in the system. Rationalists generally try to model out random, or treat it as an error function. Bur random also means that on each occasion an event happens it can have different consequences. This is true of interest rate changes. On some occasions a rate change is followed by a rise in the exchange rate as investors bring in foreign exchange to take advantage of the higher rates. On other occasions the rise is followed by a fall in the exchange rate as investors see this as a signal that the economy is overheating. Either can be rationalised, but in advance of the impact the outcome is effectively unknown.

Historic data can be used to generate a probability distribution, it is true. So the planner can know that most of the time the exchange rate will rise, but perhaps 20% of the time it will fall. This brings us back to resilience. Are plans robust to the 20% of occasions there is a fall? If they cannot be robust, can they quickly be switched?

Military planners know that all possibilities need to be rehearsed so that quick decisions can be made regardless of the probability that any particular event occurs. The effective plan is one that can be implemented quickly and effectively - and before any opposition creates their own plan.

Conclusion

A conclusion that incorporating complexity into projects and programmes implies unpredictable outcomes is not very helpful. A conclusion that the range of potential outcomes is wide and a point estimate of costs or benefits impossible tends to get rejected.

Managing complexity does not mean a counsel of despair. What is does require is three important things. First identification. It is crucial to distinguish between complicated and the potential for a complex relationship which will generate accelerating move away from plan or unpredictable outcomes. In any project it will be possible to identify such points either in delivery programmes or in planning analysis.

Second, firebreaks. Where the potential for accelerating impact has been identified, a firebreak may be able to limit the potential for damage. Dividing a project up into phases, or parts which do not depend on one another limits the possibility for a cascade of failure. Of course, it might be the plan to take advantage of the potential for cascade, for example in encouraging innovation or taking advantage of agglomeration. In which case, facilitating nearness would be a better plan.

Third, knowing Plan B (and C, D, E, F etc too). Too often plans, analysis and implementation rest only on Plan A. Planners and analysts like a rational world in which only one path is possible. In the real world this is not true, and success depends on taking advantage of opportunities as they emerge and abandoning the path which is heading off target. Being able to react quickly and knowing what to do when the world changes is crucial. Keynes famously said that ‘when the facts change, I change my mind, what do you do?’ Even though this quotation, however famous, cannot be tracked to a source, it remains very relevant for dealing with complexity which requires you to be ever alert to changing facts and moreover to be ready with the appropriate action when they do.

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1. Perretti and Negro (2007) [↑](#footnote-ref-1)
2. HMT Treasury (2013) [↑](#footnote-ref-2)
3. LUTI models are described in Webtag, the guidance for project developed in the DfT. [↑](#footnote-ref-3)
4. NAO 2013 [↑](#footnote-ref-4)
5. Buchanan and Volterra 2007 [↑](#footnote-ref-5)