The contribution of system dynamics to cost benefit analysis - a case study in planning new mental health services in the UK

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Abstract

This paper presents an example of the value that system dynamics can add to conventional cost benefit analysis. A static cost benefit analysis is described for planning the supply of new mental health services across the UK and the development of this analysis into a system dynamics model is explained. By developing a bigger picture of the issue, both upstream to where patients go after treatment and downstream from where patients originate in the labour market, and by simulation of the enhanced vision, the dynamic cost benefit analysis is shown to advance understanding of the issue and plans. It questions the magnitude of the potential benefit, introduces phasing issues, surfaces structural insights, takes account of the dynamics of the labour market and forces linkages between the plan and other initiatives. An overall conclusion is that dynamic factors are often left out of cost benefit analysis simply because they cause too much complexity for decision makers, whereas system dynamics allows these factors to be included without masking the clarity of the case. The paper suggests that cost benefit analysis and system dynamics are very complimentary and should be used together in strategic planning.

Please note that any views or opinions expressed are solely those of the authors and do not necessarily represent those of any health organisation.

Introduction

There have been numerous applications of system dynamics in health in recent years. These have covered health reform (Hirsch et al, 2005), capacity planning (Lacey, 2005; Lane et al, 2000; Royston, 1999; Taylor and Dangerfield, 2005), older people's services (Wolstenholme, 1993, 1996 and 1999) and disease management (Dangerfield, and Roberts, 1999).

In particular the authors of this paper have specialised in patient flow modelling. First, at a national level to influence government policy on delayed hospital discharges (Wolstenholme et al, 2004a) and more recently to assist local heath and social care communities in the UK to interpret and apply national policy frameworks for older

people (Wolstenholme et al, 2004 b and c) and for mental health reform (Wolstenholme, et al 2006).

This paper addresses the application of system dynamics to enhance traditional cost benefit analysis (CBA) applied to planning a significant increase in the number of mental health therapists in the UK for the purpose of providing a range of new mental health treatments (Observer, 2006). The paper describes the cost benefit analysis and a system dynamics model developed to improve understanding of the people flows and complexities of transition associated with the initiative. The issues and insights raised by the dynamic analysis are presented and comments made about the role of system dynamics modelling in this type of strategic planning.

The cost benefit hypothesis

In early 2006 plans were developed in the UK to assess the benefit of making cognitive behavioural therapy (CBT), as recommended by the National Institute for Clinical Excellence (NICE, 2006), widely available to treat depression and chronic anxiety. The plan suggested that investing £600 million in 10,000 therapists would enable the treatment/recovery of 800,000 people per year and create benefits to the exchequer and society of over £2 billion per year when fully established. The benefits would arise from extra output, reduced absenteeism, extra quality of life years, savings in medical costs associated with these conditions, increased tax payments and savings in invalidity benefits. It was known that there was an accrued backlog of around 1 million people on incapacity benefit (IB) due to mental illness and the CBA assumed that this level of investment and numbers treated might be expected to eliminate the backlog in 7 years.

Benefit coefficients per person were derived based on well researched sources, averaged over 6 classes of mental health condition and taking account of spontaneous recovery rates. Cost coefficients were derived based on the costs of employing the number of therapists required to treat this number of people per year based on the number of people each therapist might treat. The overall net cost and benefit coefficients were then multiplied by estimates of the number of people whom it was thought might be possible to treat with CBT to give annual returns achievable in steady state, once the new treatment system was established. Estimates were also given as to where the extra therapists might be sourced.

The system dynamics model

The system dynamics model initially incorporated the derivation of the cost and benefit coefficients per person as in the cost benefit analysis. The idea of this was to demonstrate that the derivations were reproducible in a dynamic model and to allow changes in assumptions within these calculations. However, as the project developed the focus of the investigation centred more and more on modelling and questioning assumptions about the numbers of people who might be treated based on the flow of these people into and out of the proposed new service and the availability of therapy capacity. This trend resulted eventually in the cost and benefit coefficients being fixed within the model to simplify the overall structure.

Figure 1 shows the system dynamics perspective broken down into 3 sectors surrounding the single state of treatment used in the cost benefit study. These are the treatment and recovery sector – the dynamics of where people flow to, the labour market sector – the dynamics of where people flow from and the therapist sector – the dynamics of therapist capacity available.

The treatment and recovery sector allows for assumptions about waiting for treatment, length of treatment, drop out rates, recovery rates, employment rates (dependent on jobs available) and relapse rates.

The labour market sector allows for assumptions about the labour market and the flows of people into the new treatment system from those with mental health conditions in employment, from those out of work and claiming IB, both short term and long term.

The therapist sector allows for assumptions about therapist recruitment, therapist leaving and case load.

Each of these sectors raised interconnected issues.

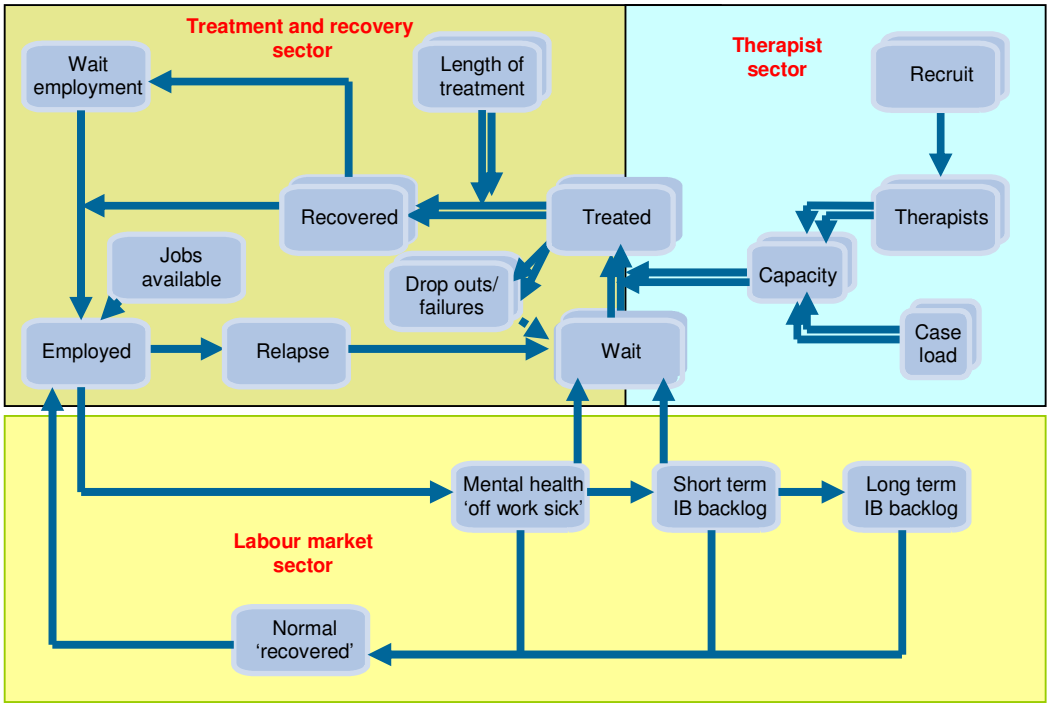

Figure 1 Overview of the structure of the system dynamics model

Issues raised in the treatment and recovery sector

The main issues raised here were:

1. The distinction between treatment, recovery and employment. Although it was stated in the CBA that there was a 30% failure rate associated with cognitive

behavioural therapy, it was not clear whether it was being suggested that 2.5 million people would be treated to achieve 800,000 recovered OR 800,000 would be treated to achieve 270,000 recovered. The *benefits* expressed in the CBA were based on 800,000 people recovered and back in employment, but the feasibility of using 10000 therapists to treat 2.75 million people was very questionable since the length of treatment achievable would be less than the minimum considered clinically feasible.

2. The cost benefit analysis assumed that every one treated had a job to return to whereas the perspective here suggested that some people (varying with location) might not have a job to return to and that job availability and the sigma attached to mental health treatment would conspire against people in seeking a return to work.

3. The CBA did not allow for any relapses after treatment.

4. The focus on length of treatment and source of people led to thinking about having a mixed rather than single programme with two treatment channels using different types of therapists as indicated in Figure 1. The first channel would contain a high intensity programme for those with greater need and the second a low intensity programme for those with lesser needs. An additional consideration here was whether people failing the low intensity treatment would 'step up' afterwards to receive the high intensity treatment.

Issues raised in the labour market sector

The main issues raised here were:

1. What would be the candidate population for the new treatment and how many people would be available for treatment? Although it was known that there was an accrued backlog of around 1 million people on incapacity benefit (IB) due to mental illness with inputs and outputs of around 260,000 per year, there was limited data available about the overall flow of people with mental health problems through the labour market. For example, the numbers off work due to mental illness. Figure 2 shows a more general structure of the labour market from which the states of Figure 1 were derived.

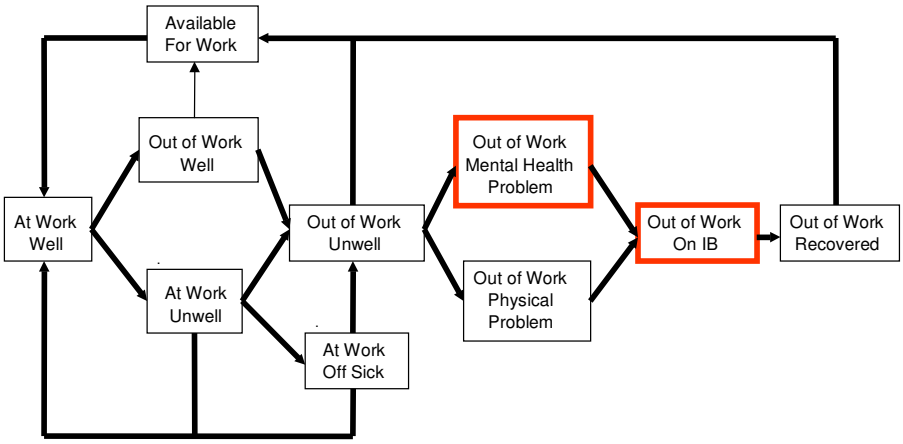

Figure 2 A broader overview of the labour market

2. How did people recover from mental in illness at present? The modelling led to thinking about and determining estimates for how long people were out of work due to mental illness and this led to an explicit statement that the main benefit of the new system would be to not only to increase the return to work of many more people than at present, but also to speed up their return.The modelling also led to the thinking that there were really two states of people claiming invalidity benefit. A short term cohort who recovered either without treatment of from the current limited current NHS provision and a long term cohort whose chances of returning to work diminished the longer they were in this state.

3. The link to other initiatives for assisting people to return to work from both physical and mental illness. Once the perspective of Figure 1 was developed it became clear that there were overlaps between the proposed use of CBT and numerous other central and local initiatives to help people back to work. Clearly ant case for funding CBT needed to explain its how it complimented these other ideas.

Issues raised in the therapists sector

1. The number of therapists needed in steady state? Following on from the idea of two service channels using two different types of therapists, the modelling hypothesised that fewer therapists would be needed overall for a mixed programme than for a single programme.

2. The build up of therapist capacity. The CBA focussed mainly on the steady state situation after full implementation of the new system, but suggested that there would need to be a progressive increase in therapist recruitment and training from two sources over a seven year period. The modelling added to this thinking by considering therapist turnover and by being able to test alternative training policies.

3. The number of therapists needed beyond seven years once the accrued backlog of people in the labour market had been drawn down and a new equilibrium had been established.

Model experiments

The issues raised by the modelling led to data assumptions and experimental design for running the model of Figure 1 for policy testing. The model was run in each case for 7 years in days and the range of experiments fell into 3 groups:

1. Running the model to show the benefits when the programme was fully operational as a comparison with the CBA for both single and mixed treatments, with and without step up from the low intensity to high intensity channels for some of those who failed to respond to the low intensity treatment. These runs assumed all therapists to be in place and a constant number of people per year presenting for treatment.

2. Running the model to show a phased build up to therapist capacity over 7 years for mixed treatments, again with and without step up and for a progressive drawdown of people from two states of the labour market ('off work with mental health conditions' and those people receiving 'short term invalidity benefit'). Assumptions were made here about the flow of people through the labour market. This data covered the length of time spent out of work due to mental illness and the current rates of return to work.

3. Testing the sensitivity of the new programme to lapses after treatment and job availability.

Results from running experiments to show the benefits of the 'Fully operational' CBT programme

A Single Programme

Figure 2 shows the number of therapists, number of people treated per annum, number of people recovered per annum, length of treatment in days and the overall net benefits per annum in £ billion to be expected from a full operational single programme

	Base comparison with the CBA	Alternative 1	Alternative 2
Therapists	10,000	10,000	6,800
Numbers treated per annum	2,750,000	800,000	900,000
Numbers recovered per annum	800,000	270,000	450,000
Length of treatment in days	44	77	49
Net benefits per annum (£billion)	2.27	0.56	0.8

Figure 2 Model results for a single programme when established

The first column on Figure 2 is a direct validity comparison with the basic CBA and shows 10,000 therapist being used to treat 2.75 million people per year with a 30% success rate, giving net benefits of £2.27 billion. As indicated earlier, this situation was considered to be somewhat infeasible since a 44 day treatment time is incompatible with the number of sessions of treatment and the associated assimilation time needed for CBT.

The second column of Figure 2 (alternative 1) shows the much more feasible interpretation of 10,000 therapists being used to treat 800,000 people per year with a 30% success rate. This result uses a minimum feasible figure for the average treatment rate of 77 days, but since only 270,000 people per year recover the net benefits per year are only 25% of those claimed by the CBA.

A slightly better return is indicated by column 3 in Figure 2 which gives results for a further option introduced at a later date than the original CBA (alternative 2). This option assumes an alternative service configuration capable of treating 900,000 people per year. This requires only 6800 therapist, 49 days treatment time, 900,000 people per year presenting and a 50% success rate.

A Mixed Programme

Figure 3 shows the results for a mixed programme when fully established for alternatives 1 and 2 from Figure 1, for both 'no step up' and 'step up' between the programmes. These results assume a 50/50 spilt of people between the high intensity and low intensity programmes and a 50% failure rate from both the programmes.

	Alternative 1 no step up	Alternative 1 step up	Alternative 2 no step up	Alternative 2 step up
Therapists high intensity/low intensity (total)	4700/1500 (6200)	6400/1500 (7900)	3000/1500 (4500)	4500/1500 (6000)
Numbers treated per annum	800,000	1,000,000	900,000	1,125,000
Numbers recovered per annum	400,000	500,000	450,000	562,500
Length of treatment High intensity/ low intensity in days	77/25	77/25	49/25	49/25
Benefits per annum (£billions)	1.0	1.2	1.1	1.3

Figure 3 Model results for a mixed programme when established

Column 1 of Figure 3 shows alternative 1 using a high intensity channel with 77 days treatment time and a low intensity channel with a 25 days treatment time. This configuration can treat 800000 people per year and requires 4700 high intensity therapists and 1500 low intensity therapists. The net benefits per year of this configuration are double those from the single programme version of alternative 1 due to a higher assumed success rate and fewer therapists needed in total (6,200 compared with 10,000).

Column 2 of Figure 3 again shows results for the mixed programme version of alternative 1, but this time assuming that people failing the low intensity treatment will step up to the high intensity channel. This effectively means treating 200,000 more people per year in the high intensity programme – 1 million in total per year rather than 800000. So this configuration means that 6400 high intensity therapists are needed in total not 4700. However, the net benefits per year are increased beyond the costs because more people are treated.

Column 3 of Figure 3 shows the results from alternative 2 using a high intensity channel with 49 days treatment time and a low intensity channel with a 25 days treatment time. This configuration can treat 900000 people per year and requires fewer therapists in total compared with alternative 1 (3000 high intensity and 1500 low intensity therapists), giving improved net benefits per year over both the single programme version of alternative 2 and the mixed programme version of alternative 1.

Column 4 of Figure 3 shows the results assuming a step up of failures from the low intensity channel to the high intensity channel. This means treating 225,000 more people in the programme per year – 1.125m in total rather than 900000. So this configuration means that 4500 high intensity therapists are needed rather than 3000. However, the net benefits are again increased because more people are treated.

Overall, the mixed programme results would appear to give higher benefits than the single programmes and the use of 'step up' gives higher benefits than 'no step up'.

Summary of first insights from the system dynamics model

Although the system dynamics model was not really used as a dynamic model at this stage the stock- flow thinking of the model surfaced some interesting insights:

1. The differentiation between people treated and recovered. The clarification here indicated that the original net benefit claims of the CBA were unachievable since to attain 800,000 recovered people per year meant treating an infeasible high number of people per year.

2. The mixed programme provides higher returns than the single programme and requires fewer therapists.

3. Step up. The concept of step up had not really been thought through prior to the modelling and it was not appreciated that stepping up 50% of people who did not respond to the low intensity treatment to the high intensity channel would require 50% more high intensity therapists.

Results from running experiments to show the benefits of a phased build up to full operation of the CBT programme over 7 years

This section of the work actually used the system dynamics model as a dynamic model. Figure 4 shows a similar output summary of results to Figure 3. However, although the number of therapists is that achieved at the end of 7 years, the figures for the number of people treated per annum, the number of people recovered per annum

and the overall net benefits per annum in £ billion are the *average* figures over 7 years.

These results are again presented with and without step up and, additionally, this time for a progressive drawdown of people from two states of the labour market ('off work with mental health conditions' and those people receiving 'short term invalidity benefit').The final 3 rows show the percentage reduction in these stocks for each situation modelled.

Assumptions were made here about the flow of people through the labour market. This data covered the length of time spent out of work due to mental illness and the current rates of return to work. It was assumed that the 'mental health off work' stock was 1.25 million people and had an inflow per year of 1 million people. Also that the 'short term IB' stock was 0.8 million people and had an inflow of 260,000 people per year. The calculations for these draw down figures is a truly dynamic calculation since the draw down is in addition to the underlying normal throughputs of the stocks.

	Alternative 1 no step up	Alternative 1 step up	Alternative 2 no step up	Alternative 2 step up
Therapists high intensity/low intensity (total)	4700/1500 (6200)	6400/1500 (7900)	3000/1500 (4500)	4500/1500 (6000)
Average numbers treated per annum	530,000	640,000	628,000	760,000
Average numbers recovered per annum	260,000	320,000	314,000	380,000
Length of treatment High intensity/ low intensity in days	77/25	77/25	49/25	49/25
Benefits per annum (£billions)	0.7	0.9	0.8	1.0
Change in stock of 'mental health off work sick' over 7 years	-50%	-50%	-58%	-58%
Change in stock of 'short term IB backlog' over 7 years	-15%	-33%	-15%	-33%
Change in stock of 'long term IB backlog' over 7 years	-36%	-36%	-42%	-42%

Figure 4 Model results for a mixed programme phased in over 7 years and draw down of people from the labour market.

An important general point about the results of Figure 4 is that the overall net benefits per year of the plan are reduced relative to the fully operational situation, due to the progressive build up of capacity.

However, before discussing the Figure 4 results in detail it is useful to relate some of the dynamic factors underpinning them. Figures 5 and 6 show example model results supporting the results summarised in Figure 4. Figure 5 shows an example output of the progressive build up of high and low therapy capacity and people in treatment over 7 years. Figure 6 shows the corresponding draw down of the accrued labour market stocks over this period.

These graphs highlight two interesting counterintuitive factors.

The first is that the 'real' short term IB backlog is not just the one shown in Figure 1, but this plus those people failing to respond to CBT treatment.(Note that these people cannot be placed back in the short term IB stock because then we would be assuming that they could be treated again). Consequently, and particularly in the case of no step up, as was the situation in Figure 5, the real total short term IB backlog will not be drawn down as fast as linear, static thinking might predict. It will also start to rise whenever therapy capacity is fully utilised.

The second factor is that although there is no direct draw down from the long term IB backlog, this stock will decline as an indirect consequence of the drawdown of the short term IB stock. Since this is upstream of the long term stock, drawdown of it will reduce the flow into the long term stock.

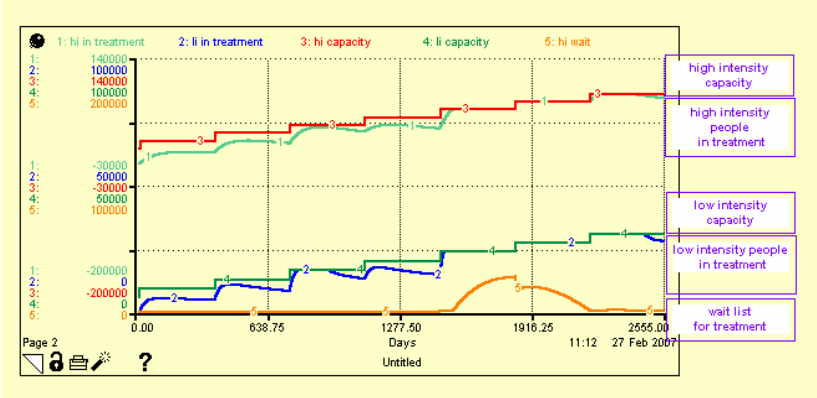

Figure 5 Example model output showing the progressive build up of high and low therapist capacity and people in treatment over 7 years.

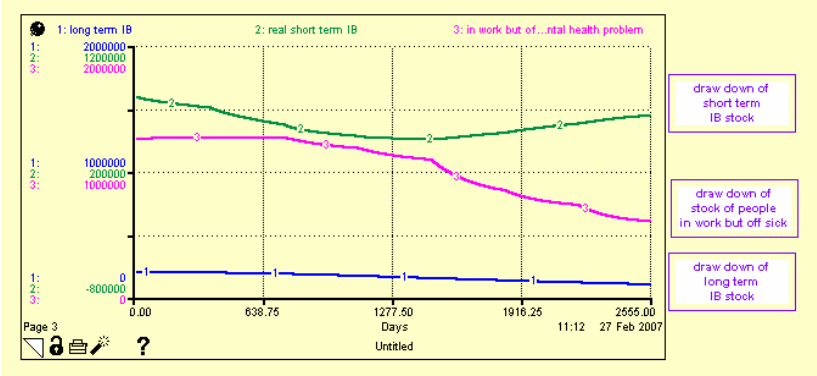

Figure 6 Example model output showing the draw down of labour market accrued backlogs over 7 years.

Returning to Figure 4, column 1 shows the alternative 1 mixed model results with 'no step up'. The 'mental health off work sick' backlog is reduced by 50%, the short term IB backlog by 15% and by default the long term IB backlog is reduced by 30%.

Column 2 of Figure 4 shows the same results as column 1, but with 'step up'. Here the impact on the 'short term IB' backlog ' is doubled, as more people are treated per year rather than placed back into the backlog (but obviously using more therapists).

Column 3 of Figure 4 shows the alternative 2 mixed model results with 'no step up'. Here short term IB backlog reductions are increased because this configuration allows more people to be treated than in the alternative 1 mixed model and introducing step up (column 4) permits even greater backlog reductions and more people to be treated per year (but again obviously using more therapists).

Although these results are not directly comparable with the CBA because two backlogs are modelled and a greater treatment rate used, it would seem that the impact of the plan on the labour market would take some time to show significant results. One reason for this is the treatment rate must not only be big enough to have an impact on the backlogs but also on the underlying inflow rates into the backlogs. In health terms it must be large enough to cope with both prevalence and incidence. In system dynamics terms it must be large enough to cope with both stock correction and inertia.

Summary of further insights from the system dynamics model

The simulation results from the system dynamics model created further insights about the overall plan in addition to those given earlier:

1. The annual net benefits of the plan would be on average 30% less during the 7 year transition period to full build up than when fully established.

2. The results from the dynamic model indicate that at best with a mixed programme and step up the impact of the CBT programme on the estimated accrued backlogs of people out of work in the labour market would take longer than 7 years to have a significant impact.

3. Due to the diminished effects of CBT highlighted in point (2) it would appear very important to run all other return to work initiatives along side the new CBT programme.

4. Structurally the modelling suggested that the best strategy would be to reduce the expensive backlogs of claimants first and then to raw down people onto IAPT from as far 'upstream' as possible in the mental health/workforce chain.

5. Step up of from the low to high intensity programmes for those people failing the low intensity programme gives a bigger impact in reducing the accrued labour market backlogs of people off work sick and on short term IB benefits, but requires more therapists.

6. The long term IB backlog will decline as an indirect consequence of the drawdown of the short term IB stock.

Sensitivity results

All of the foregoing results still assume that all people being treated by the new programme will recover, have no relapses and return to employment. The system dynamics model allows the impact of these factors to be tested. Figure 7 Shows how devastating the effect on the net benefits would be if 15% relapse occurred after 2 years and 50% of the recovered had no jobs to return to after 3 years. The result assumed that new job creation would be developed to counter these trends after 4 years.

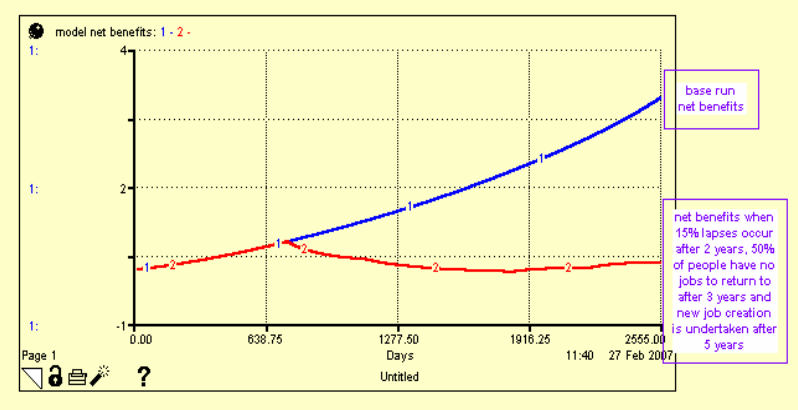

Figure 7 Example model output showing the effect of relapse and lack of job availability on the net benefits per year of the CBT treatment programme over 7 years.

Conclusions on the content of the CBA

The use of system dynamics suggested that although generally very beneficial the proposed plan developed in the CBA could be less than anticipated from a static analysis. Whist the benefit coefficients derived are sound, the main loss of impact is associated with assumptions about the flows of people. The real results would depend on the intensity of the programmes created, the phasing of introduction, the step up assumptions, the knowledge of the sources of people in the labour market, actions to counter treatment lapses and particularly actions to help recovered people back into employment.

Conclusions on the use of system dynamics to supplement CBA

It was shown possible to quickly develop a dynamic model to supplement the CBA which allows analysis and understanding to develop well beyond the CBA.

The characteristic of traditional CBA is that enormous technical and clinical research effort is put into determining the cost and benefit coefficients, but then these are multiplied by very simple estimates of the underlying resource flows.

A characteristic of system dynamics is that it enormous effort is put into studying the resource flow structure of a problem, but often little effort in converting these to flow to financial outputs.

It is suggested here that dynamic cost benefit analysis combines the best of both worlds by combining these characteristics. System dynamics can include the derivations of the coefficients, but its major contribution is to take up where the CBA leaves off and to apply the coefficients to an investigation of the underlying flow structure of the issue.

It is interesting that there was some resistance initially in the project to the development of a dynamic model of the cost benefit analysis on the grounds that this would complicate an already complex problem and confuse decision making. In the event the use of system dynamics enabled a more comprehensive analysis without losing decision clarity.

It is suggested that dynamic cost benefit analysis as described here should be a prerequisite on all planning projects and starting with a CBA is an excellent way of showing the value of the system dynamics method.

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