Computing and Engineering Distance Education Centre (CEDEC), A Systemic Approach

Mohamed Loutfi
School of Computing, Engineering and Technology, University of Sunderland,
SR60DD, Sunderland, United Kingdom
Tel +441915152787 Fax +441915153292
Mohamed.Loutfi@sunderland.ac.uk

and

Alfredo Moscardini
School of Computing, Engineering and Technology, University of Sunderland,
SR60DD, Sunderland, United Kingdom
Tel/Fax +441915152763
A.Moscardini@sunderland.ac.uk

and

Malcolm Pearson
School of Computing, Engineering and Technology, University of Sunderland,
SR60DD, Sunderland, United Kingdom
Tel +44 1915152774 Fax +44 1915153292
Malcolm.Pearson@sunderland.ac.uk

1. ABSTRACT

The paper considers the problem of capacity constraints at an educational centre. It begins with an economic analysis of the effect on capacity due to an increase in demand followed by a discussion on the limitations of such an analysis. The problem is then tackled by using Causal Loop Analysis and a System Dynamics model and a deeper understanding of the problem is obtained. Full use is made of the archetype 'shifting the burden'. Modelling using SD gives management a practical tool for solving problems especially in its treatment of delay lags.

2. KEYWORDS

System Dynamics, Distance learning, Economics, Capacity Constraints.

3. INTRODUCTION

The Centre for Distance Education in Computing at the University of Sunderland (CEDEC) is responsible for the creation, delivery and administration of a variety of computing programmes which are taught at worldwide centres remote from the

university campus. CEDEC provides a form of distance learning to students who wish to study at the University of Sunderland, but for various reasons are unable or unwilling to study at the University Campus.

CEDEC offers a variety of courses:

PhD Computing
MSc Computer Based Information Systems
MSc Management of Information Technology
BEng Mechanical Engineering with Management
BEng Mechanical Engineering with Management
BEng (Hons) Multidisciplinary Engineering
BA/BSc (Hons) Computer Studies
Foundation Degree in Mechanical Engineering with Management
Foundation Degree in Mechanical Engineering with Marketing
Foundation Degree in Engineering
Foundation Degree in Information Technology for Business

The principal objective of CEDEC is:

> "*To ensure that students studying at a distance are provided with the same high quality learning experience as those students studying on campus at the University of Sunderland*".

To accomplish this objective, programmes are delivered through a global network of Learning Centres, where students attend for regular sessions (typically twice a week for a part-time programme for 3 hours each time).

The programmes are not 'distance learning' in the traditionally accepted sense, such as at the UK Open University where students study entirely at home. The programmes require an element of attendance at a local study centre and, in each country of operation CEDEC works with a local partner who can be a college, university.. etc. The local partner provides a study centre with computing facilities; support tutors and has responsibility for advertising and recruiting students. The University of Sunderland provides all teaching materials and has responsibility for all assessment.

Many of our modules operate around a video based concept, where students watch a video (produced by Professors and Lecturers from the University), receive support from a University approved local tutor and work through tutorial materials. All assignments and tests are produced by and marked by the University module tutors. In addition tutors at the University give support to students and local tutors through the medium of e-mail and video conferencing.

In 1999 Sunderland was home to around 17,000 students from 50 countries. They were attracted to the University by its comprehensive range of high quality programmes, which allow a flexible approach to studying. Sunderland university's aim is to have as many students off campus as they have on campus.

4. THE PROBLEM

The demand for CEDEC's courses has increased every year since 1994. In 2001, we have recruited seven new partners- mainly universities. We do not know how many students this will generate. It is hoped that each centre will recruit two cohorts of fifteen students over two tears (i.e. 210 students) but the actual recruitment could lie between this number and zero. If recruitment is near the larger figure, demand will exceed capacity in 2002 (Advanced Practice Report, 2001). It was suggested that a Systems Dynamics model might help CEDEC to make the correct staffing decisions.

5. AN ECONOMIC PERSPECTIVE.

The peak/off peak demand problem is a feature of all public utilities where output cannot be stored. (e.g. electricity, telephones, Education, gas) Economic theory normally relies on the price mechanism to ration demand to available supply. Let us examine figure 1.

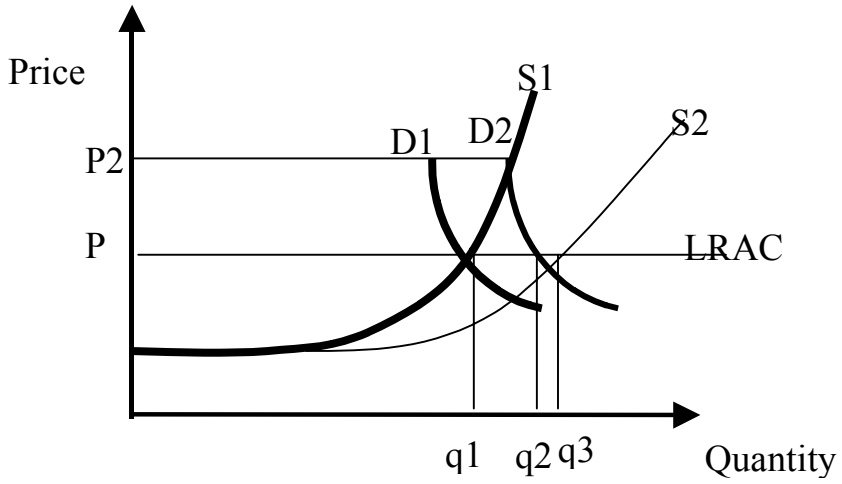

Figure 1

Given the supply curve is S1 and the demand curve D1, we can determine the equilibrium supply and demand q_1 at the price P which gives the long run average cost (LRAC). If the demand curve changes to D2 and we keep the same price, demanded quantity rises to q_2. The excess demand ($q_2 - q_1$) will be dealt with by waiting lists.. etc. D1 could portray off peak demand and D2 peak demand. If we consider a new supply curve S2 then the quantity is q_3. The rectangle generated by q_3-q_2 represents excess capacity.

In the CEDEC case there will be different demand curves for different geographical areas so the overall demand curve will be a stepped version of the above. This type of model can be used to calculate optimum profits for the centre but does not deal with the resource allocation problems caused by varying demand. The economic analysis fails to

fully capture the dynamics of the problem. However the power of system dynamics helps to understand why the movement from $q_1 - q_2$ in figure 1 might imply dynamic quantity movements with full utilisation of the system. Thus system dynamics is a useful tool in understanding and capturing the dynamic behaviour of the system (Moscardini, A. Loutfi, M. 1998)

6. A SYSTEMIC PERSPECTIVE

6.1 The Causal Model

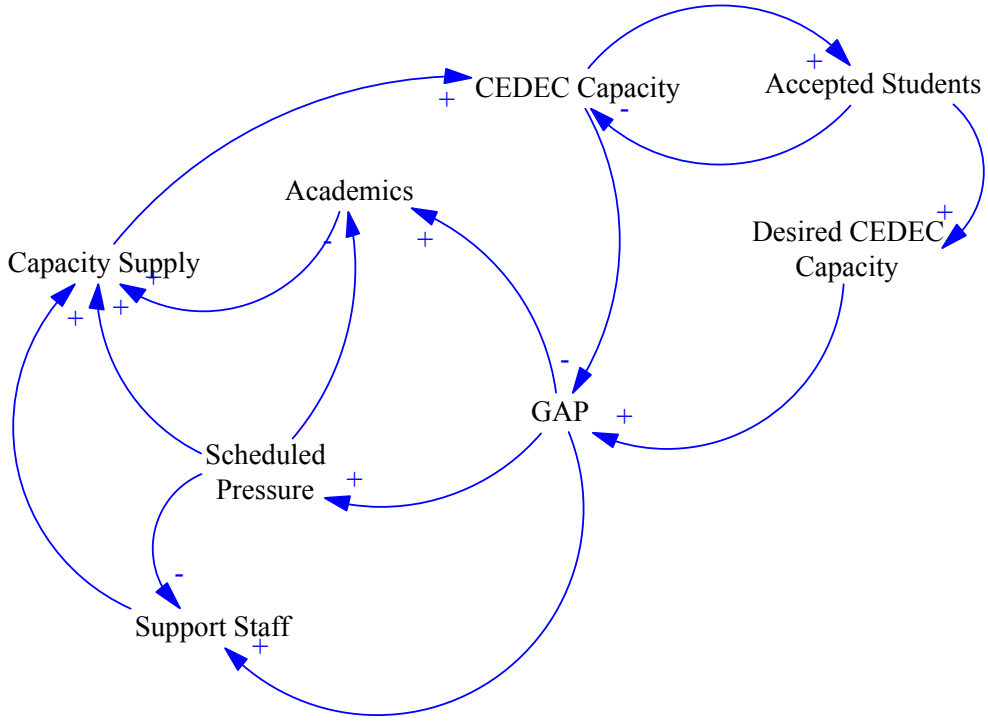

Figure 2 Causal Diagram

In the causal diagram, several terms have slightly different meanings and thus need definition.

CEDEC Capacity is used to mean the number of student places that can be supported by the current staff and resources at a particular time. For example if CEDEC Capacity is set at 500, this means that CEDEC has the ability to serve 500 students in a certain time period. When students join the centre then this diminishes the number of available places which explains the negative link between accepted students and CEDEC capacity in the causal diagram

Desired CEDEC Capacity is the capacity that is needed to satisfy demand for CEDEC services

Scheduled Pressure represents the extra workload imposed on the staff to satisfy the new demand for capacity

Capacity Supply adds extra units of Capacity. This could be in the form of extra work (short term fix) or extra staff (long term fix)

With these definitions the causal diagram is presented in figure 2.

It must be noted that we are modelling how to deal with increases in numbers not profit. Thus this is a Cournot not a Bertrand model. We see in the model that there are three major positive feedback loops which indicate the problem can be solved by increasing workload or employing more staff. But the negative link from Scheduled Pressure to both Academics and Support Staff indicates that burn out will occur and thus switch from the short term to the long-term solution

6.2 Shifting the Burden

The last remark indicated that there may be an archetype behind this model. The archetype "shifting the burden " (Senge, 1990) is in fact present. This is composed of two balancing loops and a reinforcing loop and shown in figure 3.

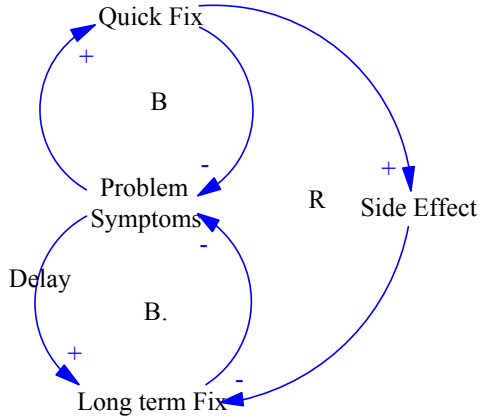

Figure 3 "Shifting the Burden"Archetype

This archetype reveals the two different ways of solving the problem of excess demand. To meet short-term increases in demand, a quick fix can be used. This short run remedy is very fast and can be introduced whilst working on long-term remedies. Excessive use of the short-term fix, unfortunately, can have unpleasant side effects and effect the long term solution making it eventually unfeasible.

The long-term fix is to build new capacity. This takes time and resources. In the CEDEC case, the quick remedy of using overtime payments to staff is modelled in the causal model by scheduled pressure. It solves short run demand problems and is flexible. However, the only real long run solution is to build up new capacity as eventually, too much enforced overtime will cause burnout and the staff will leave thus putting more pressure on the staff that are left.

6.3 the System Dynamic Model

The System Dynamics model follows the causal diagram. The level of suport (CEDEC Capacity) is diminished by new students and can be increased by Capacity Supply. The driver for this is named GAP which is the difference between the desired and the actual capacity. Capacity Supply can come from physical replacements or from Scheduled Pressure.

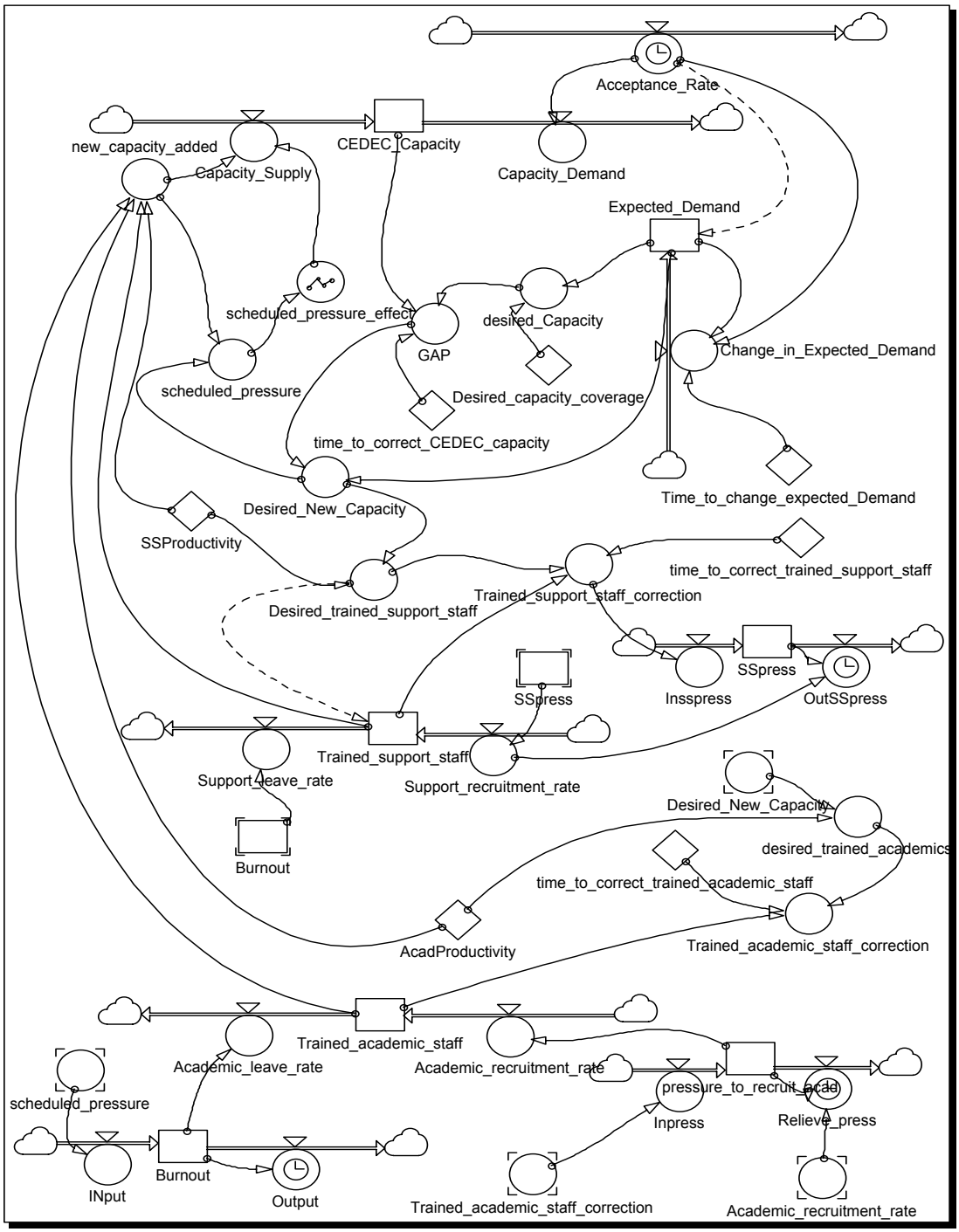

Figure 4 System Dynamics Model

Scheduled Pressure represents the percentage of extra work which support staff must undertake. A record is kept of this in the stocks SS Press and Pressure to recruit Acad. Once the build up is equivalent to an extra member of staff then the recruitment process is turned on and a new member is eventually recruited.

A record of how many weeks all members of staff works at a rate more than 50% over normal is also kept. After a fixed period of time of working at that rate, burnout is adjudged to have taken place and a member of staff drops out.

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6.4 The Model Behaviour

We can now use the model to consider solutions to the peak demand problem. We will demonstrate how the model can explain these issues and different ways of solving this problem.

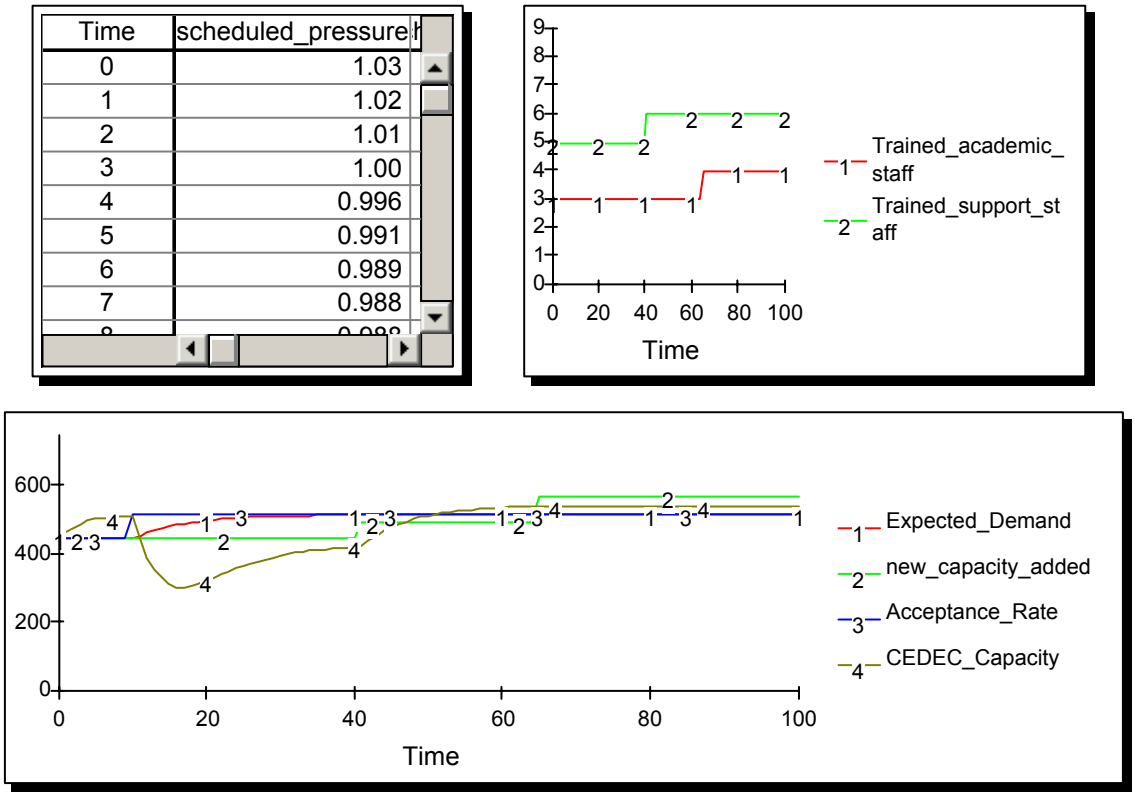

Figure 5

Total supply of the education services can be classified into capital building functions and human resource (short run) functions. Forecasts for 2002 anticipate that a total utilisation rate of 520 students due to the 7 new centres added. Normal capacity operations will accommodate 450 students per week. Total expected excess demand is therefore 70 students per week. This excess demand could go up to 210 students if all the 7 universities start recruiting and at the same time

The model is in equilibrium for the first 10 time steps, after time step 10, there is sudden pulse in demand which is explained by the expected increase of students, which is due to the new centres coming on line at the same time. This pulse destabilises the model and reveals the dynamic nature of the problem of peak demand: capacity problems.

This discrepancy is at maximum when the pulse appears. From then on, the expected demand stock. The capacity correction and the expected demand drives capacity/supply which rises above the acceptance rate before it settles into equilibrium. The capacity/supply adds to CEDEC capacity when the desired capacity and the expected demand are both rising. This makes sense, as the management in CEDEC would like to have more capacity to cover expected future demand.

The model suggests that one extra academic and one extra support staff is needed to cover the extra demand but even then, all staff are working at 20-30% above normal. Thus the quick fix is in evidence.

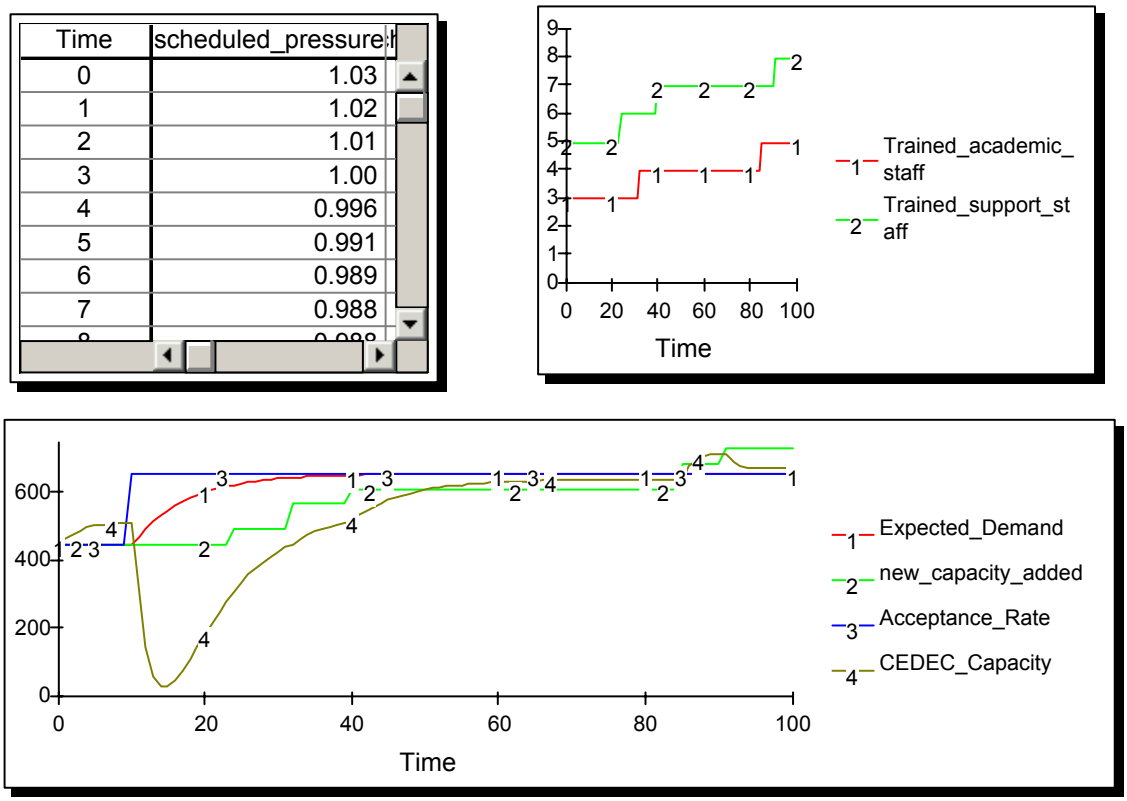

Figure 6

In figure 6 we look at the extreme case if all 210 possible students come on line. Here the oscillations are much greater as the capacity is almost doubled but we can see that the model again stabilises with extra staff. Unfortunately, they are all working at 60-70% over normal.

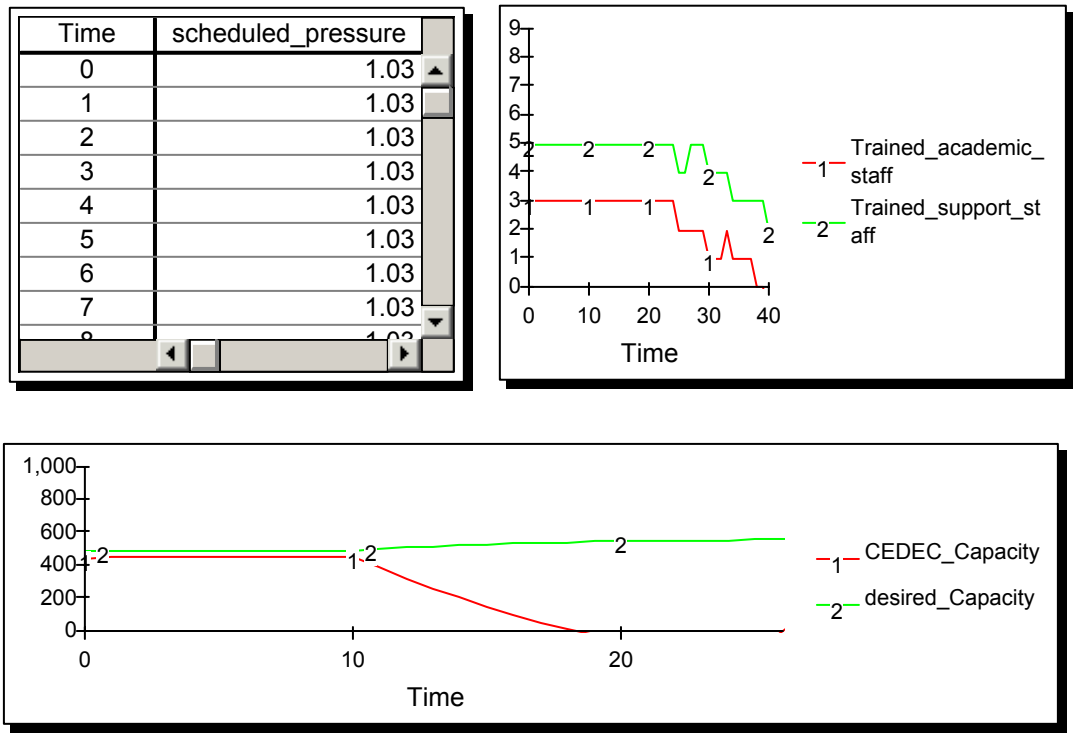

Figure 7

In the first two cases the Burnout factor was not switched on. In figure 7 we see the effect of this. The period was set to ten weeks so if all members of staff worked more than 50% over normal for ten consecutive weeks, then it is assumed that someone will break and leave.

We can see that this indeed does happen and a member of staff leaves after 25 weeks. Once this decline has taken place, the system cannot cope and the centre would collapse.

7. CONCLUSION

The paper shows how the peak demand capacity problem can be tackled dynamically. The economic analysis is a comparative static case. It does not capture the mechanism of meeting short run excess demand problems. The System Dynamics modelling allows management to configure the short run issues of demand vs. capacity with workable scenarios till new capacity comes on stream. The paper also shows the danger of relying on overtime to solve the problems of variable demand. It demonstrates that the only workable solution is to build up resources and not overwork the staff. Modelling using SD gives management a practical guide to problem solving and configures delay lags in a way which is a significant management tool.

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Back to the Top