# DOES STOCK CONTROL NEED MODELLING OR SIMPLY EXPERIENCE? SYSTEM DYNAMICS OF HOSPITAL LINEN

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**Abstract**

The St. Radboud Hospital of the University of Nijmegen, The Netherlands is sponsoring a System Dynamics computer simulation designed to study the hospital's textile (bed, catering, medical linen and uniforms etc.) circulation process.
Textile cycles between department stock, in use, laundry, distribution stock and the various transport phases.
The costs are of the order of:
* Dfl. 60.000 per year replacement.
* Dfl. 2.500.000 per year laundry.
In calculating the yearly additional budget for replacement stock the administration uses a rule of thumb method in which ca. 9 times the average daily issue is taken as the total stock in circulation. This ordering rule proves adequate in the case of the ca. 50 textile articles for the roughly 50 departments but in an appreciable number of cases it leads to greater or smaller stocks than required.
The model is being used to investigate the factors in the circulation system that are important for cost and stock sizes related to the several articles.

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## INTRODUCTION

The aim of this paper is simply to highlight some practical aspects of using the System Dynamics modelling approach in the fairly well known area of stock control.
The authors interests were concerned with teaching-bound research on the one hand and practical stock control on the other.
The problem arose in a ca. 1000 bed Hospital during review of budgetary calculations. Rule of thumb methods had been developed by experience for determining the relation between daily avarage use of linen items such as bed sheets and the total required stock. Practically irrespective of type of article (sheets, towels, napkins, etc.) the budget used a multiplier of say, 9 times the registered daily average during the previous year to determine the required total stock. This amount less the counted existing stock gave the numbers to be budgetted and in time, requisitioned.

It was known of course that the relationship between average numbers used and the corresponding total stock required was very dependent on the type of linen article and the use-wash-stock and reuse cycle it went through. In fact the administrative system available could provide all sorts of stock taking counts and patient numbers per category. In this sense there was no lack of information. What was lacking was the deeper insight into the underlaying process which on the one hand led to the results counted and on the other hand formed the scientific basis for judging the seemingly stocha stic behaviour of the stock counts.

Some time before the problem was formulated in these terms the Head of the General Services Department came across an article on System Dynamics where the idea of a closed system of rotating stocks became clear to him. He asked the System Dynamics Group, Delft, for information and texts about the approach. When sending him a copy of the lecture notes anxious as always to find interesting case material and cooperative industrial clients, the Group asked if they might know more of the problem. The answer was the following problem description:

"Hospital linen follows a cycle from stock shelf in the department, use by patients, transport to laundry, laundring, transport back to the hospital and distribution to the nursing department.
The cycle-time of this process determines to a large extent the necessary investments (about 600.000 guilders per year).
Optimalization of this process once and structurally can lead to reduction in hospital running costs."

This description was enough to develope a simple model and document it throughly with a view to demonstrating what one can do with a System Dynamics approach. General knowledge and available limited experience of stock control at the Civil Engineering Management Group was enough as a basis for this demonstration Model. The systematic approach and rapidity with which a plausible if simple mathematical simulation model of a - in practical terms - relatively complicated system was producted convinced the Hospital Head of Department.
The method could provide the necessary basis for a better understanding of the behaviour of the linen stock system. This understanding was necessary to evaluate possible cost saving policy alternatives.
This conviction leed to a ten man-weeks research cooperation contract with Delft/University.

## DIFFICULTIES WITH THE CAUSAL LOOP DIAGRAM

Although the prebliminary model was presented in the conventional way, starting with a causal loop diagram, this proved in fact quite difficult. The basic diagram is as Fig. 1.

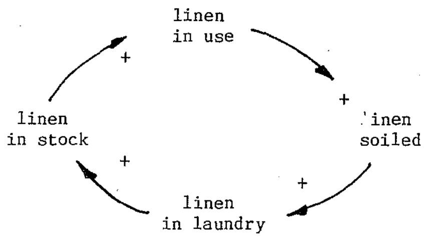


**Figure 1: The basic linen cycle**

The more linen in use the more soiled, the more to be launderd, the more eventually in stock. the more can be used. Very clear, but this means a positive feedback loop (all influences positive, see + signs) suggesting growth our decay and not the self-regulation evidently present in such a stock system. Somewhere there must be negative feedback. Figure 2 seems to have solved the matter but we cannot help feeling that the earlier criticism of Morecroft (1982) is here proved again: The causal loop diagramming presupposes a mental structuring of the system which may even require a preliminary structuring in more schematic-physical terms. And figure 1 is that in fact, as it simply shows the flow of linen in the system.

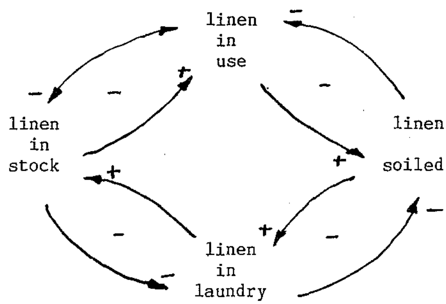


**Figure 2 : Self stabilizing basic causal diagram**

In other words, it often happens that formulation of the problem in terms of a (physical) flow diagram is methodologically prior. Figure 3 shows the flow diagram eventually resulting after discussions with the Hospital representatives.

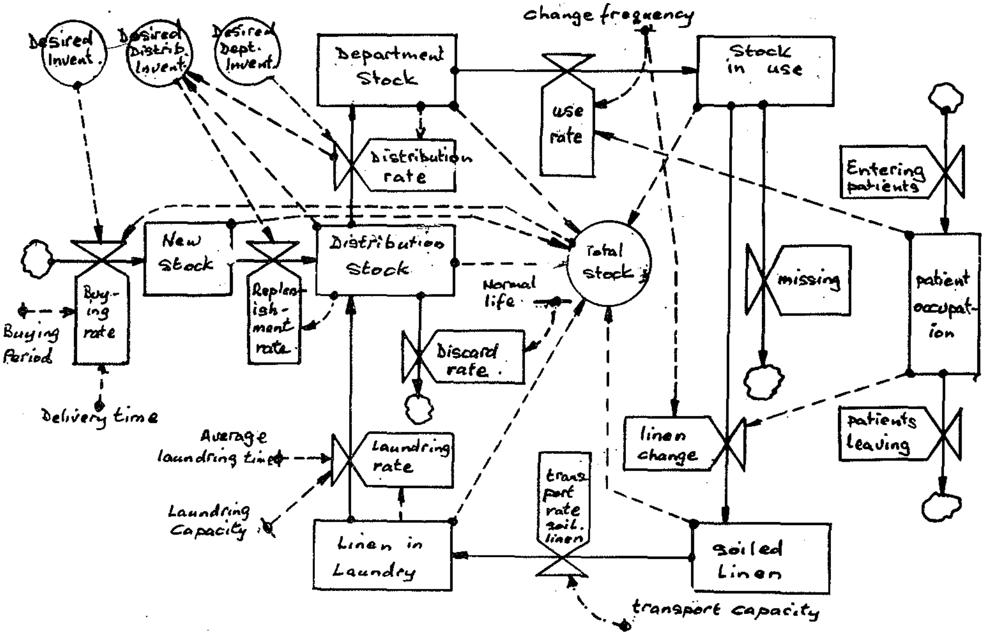


Figure 3: (DYNAMO) Flow Diagram of Hospital linen system

## FIGURES VERSUS FACTS

One of the more laborious facets of modelling a system is getting all the available quantitative information into a form suitable for inclusion in the model. As the model is by definition a simplification of reality the empirical information from reality has to be fitted to the hypothetical structure that the model is. A second reason why this process is laborious is the shear quantity, number, of figures to be tailored to the model. In this case 52 types of linen had to be related to 32 specialist departments each with their separate frequency of use and stock levels.
This matrix of types and uses was conveniently included in the model using the array facility provided by DYNAMO III, version 1.04 (Pugh 1976).

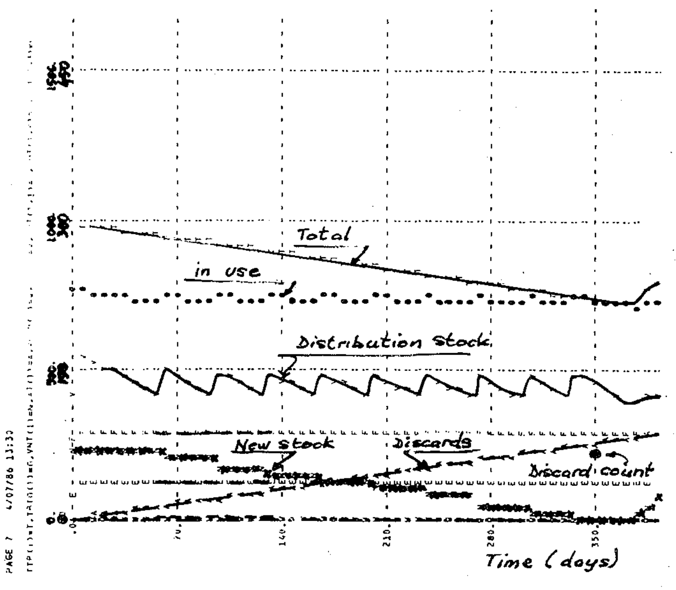


**Figure 4: Sample run, bed sheet stock**

Figure 4 shows a sample run for linen used in the departments. It is interesting to look a moment at the line indicating the level of "discarding" (through wear or loss) linen for instance. This line is based on estimated number of uses before discarding. At the end of a year the value arrived at by the model can be compared with the actual stock counts of discards. In this case (figure 4) the discrepancy is not very large.

This is one simple example of how a model helps you to check the empirical figures with model facts. This example also brought to light that very little was known about actual wear values per linen article, especially because registered discards also included loss due to unknown causes, for instance theft. The model results seem to be able to clarify this point and are giving the insights necessary to take the appropiate policy decisions.

For instance, the trade-off between light weight, cheaper to buy and to launder, linen and dearer heavy quality with less wear is now being investigated.

## MODELLING DISCRETE EVENTS WITH DYNAMO

Without going into the whole discussion on the relative merits of discrete versus continual simulation programming languages, as has already been demonstrated by Wolstenholme and Coyle (1980), the software packages used in System Dynamics are capable of describing quite discrete elements in system decision variables. Patients stream in and out mainly Monday to

Friday and according to speciality have different average lengths of stay in the hospital. The laundry and transport services work only Monday to Friday morning but bedlinen is also changed on the weekends.
As an example, the following equations made it possible to simulate the weekly work cycle in the Hospital.

```
L      TD.K=TD.J+DT-DAG.J    TIME OF DAY (MORNING OR AFTERNOON)
N      TD=TD1
C      TD1=0
A       DAG.K=CLIP(1,0,TD.K,.5)

L      TW.K=TW.J+DT-WEEK.J  TIME(DAY) OF WEEK
N      TW=TW1
C      TW1=0
A      WEEK.J=CLIP(7,0,TW.K,6.5)
```

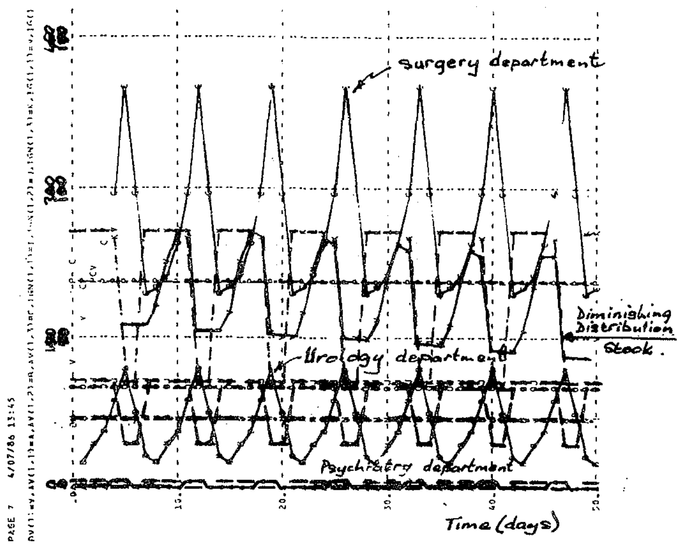


**Figure 5: Weekly bed sheet stocklevels for three departments and the diminishing distribution (total stock)**

Figure 5 shows that the equation construction used results in model behaviour which reproduces actual behaviour. Monday morning activity begins to lower the soiled linen stock and restock department stocks from the distribution stock. At the end of a workweek the department stocks are at a level sufficient to bridge the weekend after which the process begins again. In figure 4 wear and missing incidence is shown as a continual reduction in total stock per article.
It is clear that programming even such relatively simple discrete decision structures requires a certain level of competance and programming skill. On the other hand, anyone with a minimum of practice with DYNAMO can develope these skills quickly.

## AIMS AND RESULTS

The aim of the modelling effort as expressed initially by the Hospital was optimising stock control in order to reduce costs.
Even before modelling, some thought and a very little stock control experience would indicate that cost reduction must be sought by reducing total required stock. Total investment is then less. The model makes it possible to do this systematically and a lot more.
The model gives a solid basis for calculating the absolute minimum values of stock per article required. Moreover it relates these to wear and "missing" factors thereby quantifying them on a continual, through the year basis and for dynamic seasonally changing patient work loads. It provides an experimental apparatus for testing the trade-offs for policies such as speeding-up transport and laundring, working weekends and changing use frequencies.
As laundry is paid for by weight, it makes it possible to investigate the trade-off between cheaper lightweight shorter life articles and heavier more durable qualities.

## CONCLUSION

Coming back to the initial question in the title of this paper: modelling or experience, the answer is clear. While experience, knowledge of the system is indispensible, modelling is a complement which can increase our knowledge and articulate it more usefully. On the other hand, the mix is important.
The modelling must go hand in hand with integration of knowledge of the system. The enthousiastic involvement of those responsible for Hospital policy made this a very worthwhile modelling experience for those concerned. Moreover it proved once again the versatility and practicabily of the System Dynamics approach.

## REFERENCES

Morecroft, J.D.W. (1982). A critical Review of Diagraming Tools for conceptualising Feedback System Models. Dynamica Vol.8 Part I.

Pugh, A.L. III. (1976). DYNAMO USERS MANUAL, 5th ed.
The MIT PRESS, Cambridge, Massachusetts.

Wolstenholme, E.F. and Coyle, R.G. (1980). Modelling discrete events in System Dynamics. Dynamica Vol. 6, Part I.