Simulating the dynamic effect of pharmacy staff workload on safety and performance

SIMULATING THE DYNAMIC EFFECT OF PHARMACY STAFF WORKLOAD ON SAFETY AND PERFORMANCE

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SUMMATIVE STATEMENT

Increasing number of accidents caused by the complex interactions of socio, technical and environmental factors have shown the limitations of traditional safety techniques. System dynamics simulation modelling is a powerful approach for addressing complex non-linear issues. We utilised system dynamics approach to model and simulate dynamic factors contributing to dispensing errors and backlog in a hospital pharmacy to facilitate holistic comprehension of factors impacting system performance and effects of system changes

Simulation des effets dynamiques de la charge de travail du personnel de pharmacie sur la sécurité et le rendement

MOTS-CLÉS
Analyse des systèmes, simulation, pharmacie

SOMMAIRE

Le nombre grandissant d'accidents causés par les interactions complexes entre les facteurs sociaux, techniques et environnementaux a démontré que les techniques de sécurité traditionnelles ont des limites. La modélisation de la dynamique des systèmes est une approche efficace pour résoudre les enjeux complexes et non linéaires. Dans le cadre de cette recherche, nous avons utilisé une approche axée sur la dynamique des systèmes pour modéliser et simuler des facteurs dynamiques, qui contribuent à signaler les erreurs et les retards dans une pharmacie en milieu hospitalier, afin de faciliter la compréhension holistique des facteurs ayant une incidence sur le rendement du système et des répercussions des changements apportés au système.

PROBLEM STATEMENT

High-pressure workload is currently a serious problem to many hospital pharmacy staff. Changes to the pharmacy staff's role, pressures to meet targets, staff shortages and long working days with no opportunities for rest breaks have led to pharmacy staff with a high workload and increasing dispensing errors. This led to concerns that patient safety is being compromised. Berwick's review into patient safety (Berwick, 2013) crucially highlighted the urgent need for developing methods and guidance for staffing ratios based on a dynamic understanding of staff workload and systematic approach.

RESEARCH OBJECTIVE/QUESTION

This project aims to model the dynamic effect of pharmacy staff workload on safety and efficiency allowing us to simulate/test various scenarios and optimise staffing ratio considering safety and performance.

METHODOLOGY

System dynamics is an analytical modelling methodology, its origins of which are attributed to Forrester (1961) in his pioneering work on "industrial dynamics" in the 1960s. Today, SD methodology is used beyond the industrial setting and has been applied in many different fields of study including healthcare. SD combines both qualitative and quantitative aspects and aims to enhance understanding of complex systems, to gain insights into system behaviour. The qualitative aspect entails the construction of "causal maps" or "influence diagrams" in which the system structure and the interrelations between the components of a system are explored. The quantitative aspect entails the development of a computer model in which flows of material or information around the system are modelled and bottlenecks identified. Such models can then be used in a "what if" mode to experiment with alternative configurations, flows, and resources

We developed a conceptual model (causal loop diagram) of the relationship amongst staff ratio, interruption and fatigue over a period of 24 hours. This development commenced with a systematic review of the literature, then involved a series of semi-structured interviews. The final qualitative model was finally developed using a group model building session and was articulated in terms of a causal loop diagram. Its mathematical representation was constructed in Vensim (simulation software for system dynamics modelling).

The mathematical expression of the causal loop diagram was a system dynamic model structured as 13 stocks and flows modules connected by auxiliary information to form an interdependent set of co-flows. The main outcomes of the model that were of interest in this study were the workload, interruption and fatigue trade-off impacting system performance and effects of system changes. We calculated measure output in terms of backlog and dispensing errors where backlog is the number of incoming prescriptions waiting to be labelled and dispensed and dispensing errors is the number of detected and undetected errors made by the staff.

The three main loops can be summarised as follows:

- Loop 1: Increase in workload, decrease time to self-check for errors, increase in dispensing errors, increase in rework done, increase in backlog, increase in workload (reinforcing loop)
- Loop 2: Decrease in qualified staff, increase in questions from trainees, increase in interruptions, decrease in time available to dispense prescription, increase in dispensing errors, increase in undetected errors, increase in patient harm, increase in qualified staff (balancing loop)
- Loop 3: Increase in workload, increase in stress, increase in fatigue, increase in dispensing errors, increase in undetected errors, increase in patient harm, increase in staff, decrease in workload (balancing loop)

We developed the base model using exogenous inputs for the model parameters extracted from a series of interviews with practitioners, pharmacy databases and literature. Verification performed included logical tests, sensitivity analysis, and sense checking from the stakeholders. Validation of the model was undertaken for each three scenarios for which sufficient quality data were available from the hospital dispensaries. We created variants of the base model for the scenarios based on a generic hospital dispensary. We customised the model to each hospital pharmacy dispensary allowing them to change the model's baseline values to match their respective hospital pharmacy dispensary such as the number of incoming prescriptions per hour, the number of staff and the number of prescriptions queried. Once the base model and variants were developed, we performed a simulation for each dispensary to establish outcomes for the simulation period and how this affects system performance. For all simulations, the dispensary boundary was considered the scope of the model.

The simulation modelled three different scenarios.

Scenario 1: effect of staff ratio and skill-mix on workload and errors. The objective of scenario 1 was to examine the trade-off between efficiency (production) and thoroughness (safety) by analysing staff levels (resources) and their impact on performance. Analyse how number of labellers and checkers can have an impact on production and errors (safety).
Scenario 2: effect of interruptions on performance and errors. The objective of scenario 2 was to achieve a trade-off by examining the effect interruptions (questions from co-workers and trainees) can have an effect on efficiency.
Scenario 3: effect of high workload on fatigue and errors. The objective of scenario 3 was to examine and analyse how the level of workload has an effect on fatigue and eventual burnout which in turn has an on capacity and errors.

Inputs into the model were from the stakeholders and healthcare databases data in 3 main categories. First were the incoming urgent and non-urgent prescriptions received per hour by each hospital pharmacy dispensary. The urgent prescriptions have priority over the non-urgent, and this is simulated in the model. Second were the number of staff required to effectively (lean) run a hospital dispensary depending on the number of machines available. This includes the maximum capacity of each staff group when it comes to dispensing the prescriptions. This was obtained from the hospital pharmacy dispensaries. Third were the errors data showcasing the number of errors committed by each practitioner allowing us to fine tune the model.

RESULTS

The simulation results demonstrated the trade-off between efficiency and safety. The results revealed how the level staffing ratio, interruptions, workload and subsequent fatigue have an impact on safety and performance of the pharmacy dispensary as a whole. The results were presented to pharmacy managers/staff using learning based interactive dashboard. The dashboard presents three scenarios, allowing pharmacy staff to interactively change inputs to see how it impacts the performance and proactively interpret the results

Scenario 1

Scenario 1 examines the trade-off between efficiency (production) and thoroughness (safety) by analysing staff levels (resources) and their impact on performance. It analyses how a number of different types of staff can have an impact on production and errors (safety). This is presented in Figure 1 where four different graphs are displayed based on data obtained from a Leicester-based hospital pharmacy dispensary. They are compartmentalised in four different sections: incoming prescriptions received by the dispensary per hour, outgoing dispensed prescriptions per hour, the workload of the staff, the backlog generated and how that impacts the number of errors committed. The graphs show the default baseline obtained from the dispensary which is based on a ratio of five labellers and two checkers.

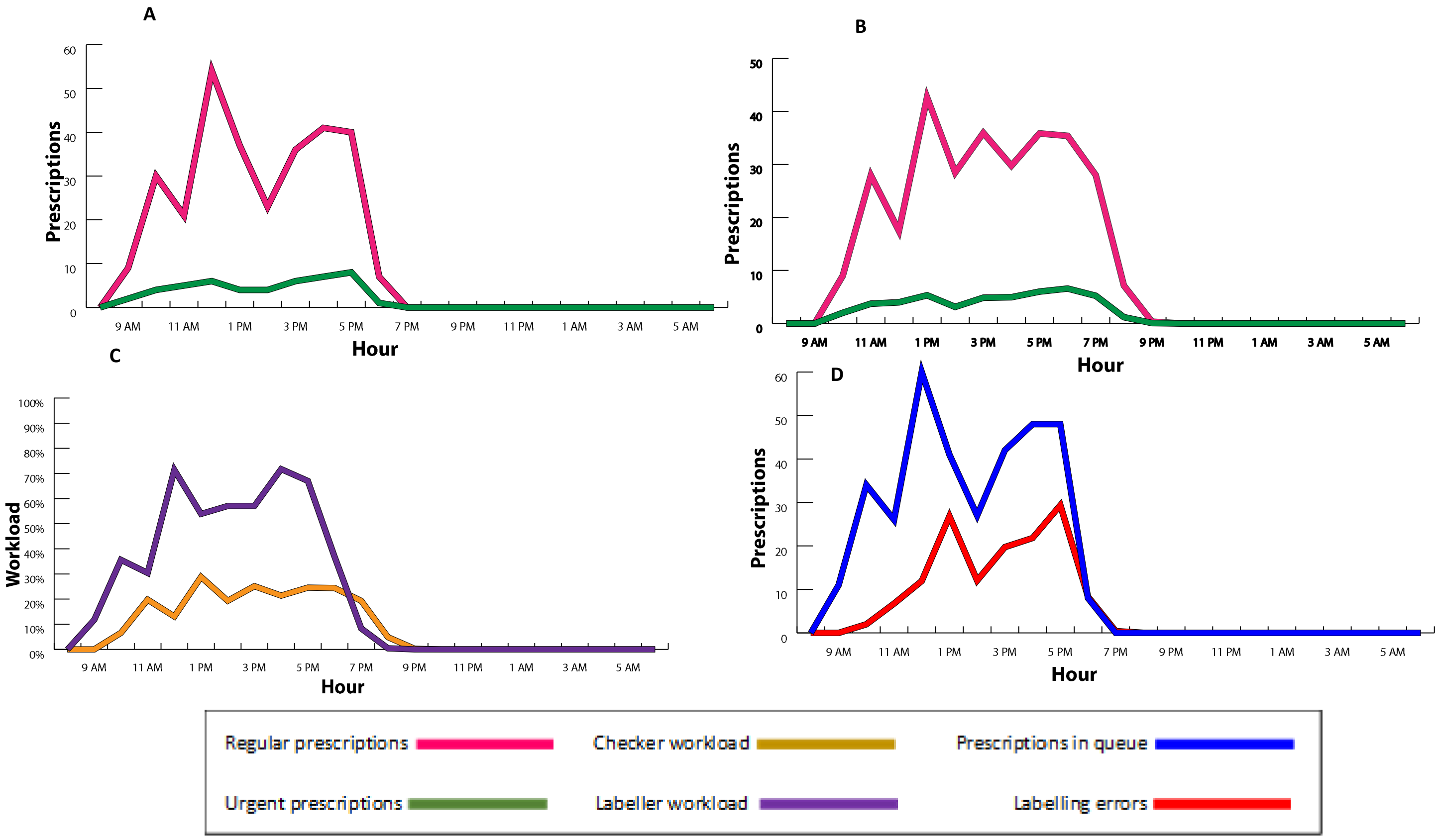

Figure 8: Scenario 1 for (a) incoming prescriptions; (b) outgoing prescriptions; (c) staff workload; and (d) backlog metrics

Scenario 2

Scenario 2 examines the balance by examining the effect interruptions (questions from co-workers and trainees) have an effect on the level of efficiency. Interruption is calculated on the percentage of incoming prescriptions that are queried by trainees and co-workers. Every query is equivalent to one prescription that could have been dispensed. Figure 2 shows the baseline data obtained from the Leicester-based dispensary revealing that around 20% of prescriptions are questioned. This is equivalent to an average of 10% efficiency performance lost by labellers and 5% by checkers. However, at times, when the incoming prescriptions double and the staff levels stay the same, the number is much higher can be off-set by increasing the number of qualified staff. This scenario allows staff to find a balance in the number of staff available and the number of incoming prescriptions that are queried so as to balance the performance of the system.

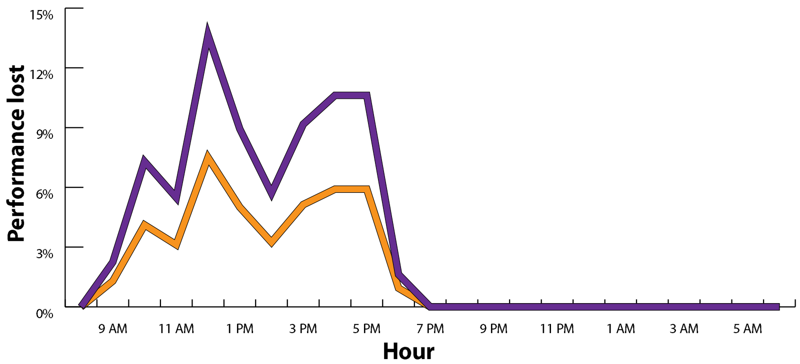

Figure 9: Scenario 2 for efficiency loss depending on the number of questions asked (interruptions)

Scenario 3

Scenario 3 examines and analyse how the level of workload has an effect on fatigue and eventual burnout which in turn has on capacity and errors. The model takes into account that 85% and above workload can be maintained for a number of hours before fatigue kicks in, this has been validated through interviews and is illustrated in Figure 3. Once the continuous high workload is maintained over a number of hours, fatigue kicks in and an hourly reduction of capacity by 5% is applied until the workload downsizes to below 85%. Once that happens, an hourly restoration rate of 10% is applied. The graphs reveals that once fatigue kicks in, the number of errors committed shoots up exponentially until it stabilises.

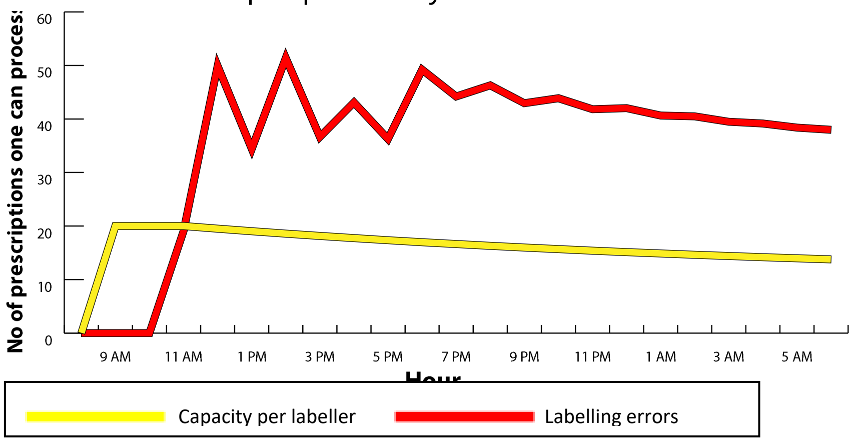

Figure 10: Scenario 3 for capacity loss due to high workload

DISCUSSION

We developed and applied a quantitative system dynamics model to show the potential consequences of factors that impact hospital pharmacy dispensary safety such as workload and staff ratios, interruption and fatigue whilst providing settings to intervene to ameliorate the worst-case scenarios using backdrop metrics of backlog and dispensing errors. This is coupled with effective forecasting of how different decision-making policies lead to different kinds of system behaviour. To be useful, a model needs to include only a necessary and sufficient number of components (Sterman, 2004).We tested the validity of the model based on the data that we received and group discussions that we conducted. The evidence has suggested that the model is a sufficiently accurate account of reality to provide lessons on safety performance within the dispensary.

The model reveals how well-intended efforts prove to be disastrous after passing of time. The staffing ratio management in the dispensaries that the model has been tested recruits a large number of trainees in order to keep the costs down and perform the same level of work as a qualified staff. The model reveals that whilst in the short term, the backlog is reduced to a minimum, in the long run, the number of detected errors kept increasing exponentially as the number of rework done to correct the errors contributed to the backlog. Furthermore, since the trainees had a reduced capacity in comparison with the more qualified staff, they were more prone to burnout which again contributed to the number of errors committed. The model forced the stakeholders to take into the account a varied skill-mix of various capacities to counteract growing backlog and errors and keep the workload to an acceptable standard.

Because we focused on the dispensary system, only the task flow of labellers and checkers were developed in detail, and we reported only the performance indicators of these two groups. The model could be further refined by adding the task flow of administrators (receptionists), and several subsystems that have a clear impact on the safety performance of the dispensary such as (automatic) robots, staff on the wards, the types of prescriptions and the role of clinical checkers which is performed before labellers label the prescriptions.

CONCLUSIONS

This paper presents that under-performance of dispensary system can be tracked down to the inadequacy of the tools and methods currently used to analyse them. Whilst the dispensary system is dynamic and complex in nature, the methods and heuristics guiding decision-making in the system do not capture adequately the effects of the most important elements in the system and their interconnections resulting in their observed poor performance. The remedy to this situation is to adopt principles of system dynamics to formulate, model, and analyse the system.

In conclusion, we offer three recommendations where system dynamics approach can address complex non-linear issues in dispensary system:

- Backlog can be prevented or significantly minimised with the right set of staff and skill-mix, taking into account the respective capacity of each staff group including trainees.
- Increasing number of qualified of staff reduces questions from trainees/co-workers but trade-off needs to be applied to what is an acceptable number of loss of efficiency.
- Introducing a five-minute break every three hours prevents build of fatigue and eventual capacity depletion leading to more dispensing errors committed.

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