Risk Map as a Library Management Information Dashboard: A Case Study in Adapting a Configural Display

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ABSTRACT

In this paper, we report on our application of Cognitive Work Analysis to create an Abstraction Hierarchy model that helps librarians identify key functional relationships for managing the overall performance of a library. By themselves, functional relationships are not as useful in providing insights into the reasons for good or poor performance. However, when these functional relationships are set against the context of system invariants and constraints, they can provide library managers information useful for diagnosis and localization of problems. We propose the Risk Map visualization technique as an information dashboard to cognitively access these functional relationships. Furthermore, when these functional relationships are portrayed over time, trends and patterns can be detected with relative ease.

Keywords

Risk map, configural displays, functional relationships, key performance indicators, business process modeling

INTRODUCTION

The purpose of this paper is to report on our adaptation of a configural display, the Risk Map, for use in performance management of a university library. The Risk Map was originally designed for financial systemic risk analysis. The Risk Map and the human factors principles used in its design have been documented elsewhere (Wong & Lemieux, 2013). A configural display is a type of visual representation that carefully combines low level graphical elements representing performance of individual components of a system, into a display configuration designed to collectively produce higher-order visual geometries or patterns that portray the global performance of the system. These visual geometries create emergent features or patterns that are visually salient. When relevant functional relationships are mapped to these salient visual geometries they can provide very powerful ways for discerning patterns and changes in performance (Bennett & Flach, 1992, 2011).

In this study we are interested in understanding if and how configural displays designed for a particular purpose could be re-used in a completely different domain with minimal changes to its user interface. The underlying algorithms and the functional relationships and their mapping to the visual forms are of course different. The Risk Map was originally intended for monitoring stability in financial systems. Such systems may be regarded as an example of dynamic safety critical systems (Sundström & Hollnagel, 2011). Libraries on the other hand, are considerably less dramatic, although poor management can lead to the closure of the library and loss of access to the knowledge and information contained within.

In university libraries that support the term time teaching program, excessive delays in students accessing reading materials will mean that lecturers would have moved on to new topics by the time the books become available again. Such measures, when integrated into functional relationships, connect higher order goals and priorities of the system, such as the availability of resources, with the objects and functions of the system such as the circulation levels and circulation rates of books in the collections.

We are also interested in understanding how concepts and methods of cognitive systems engineering (CSE) (Rasmussen, Pejtersen, & Goodstein, 1994), and the Abstraction Hierarchy (AH) in particular, might assist in the systematic and objective identification and analysis of key performance indicators (KPIs). With the increasing interest in big data and visual analytics (Thomas & Cook, 2004) methods, we are also interested to understand how CSE ideas may be applied to develop better corporate information dashboards (Few, 2013).

We used cognitive work analysis (Vicente, 1999) to interview three senior librarians and worked with them to develop an AH of the library's operations processes. We also identified functional relationships that represent the library's key performance relationships. We applied the semantic mapping principle (Bennett & Flach, 2011) to translate the library's key performance functional relationships onto the visual geometries of the Risk Map. Three key performance functional relationships of the library's operations were rendered against the library system's invariants and constraints. We identified four broad areas that constrain and provide a visual framework for interpreting performance of the system: a "good" area to be in; a "critical" or bad area to be in; an "okay" area where performance is neither good nor bad; and a "boring" area, where elements of the system are likely to be consuming resources with no real benefits to the organization's goals.

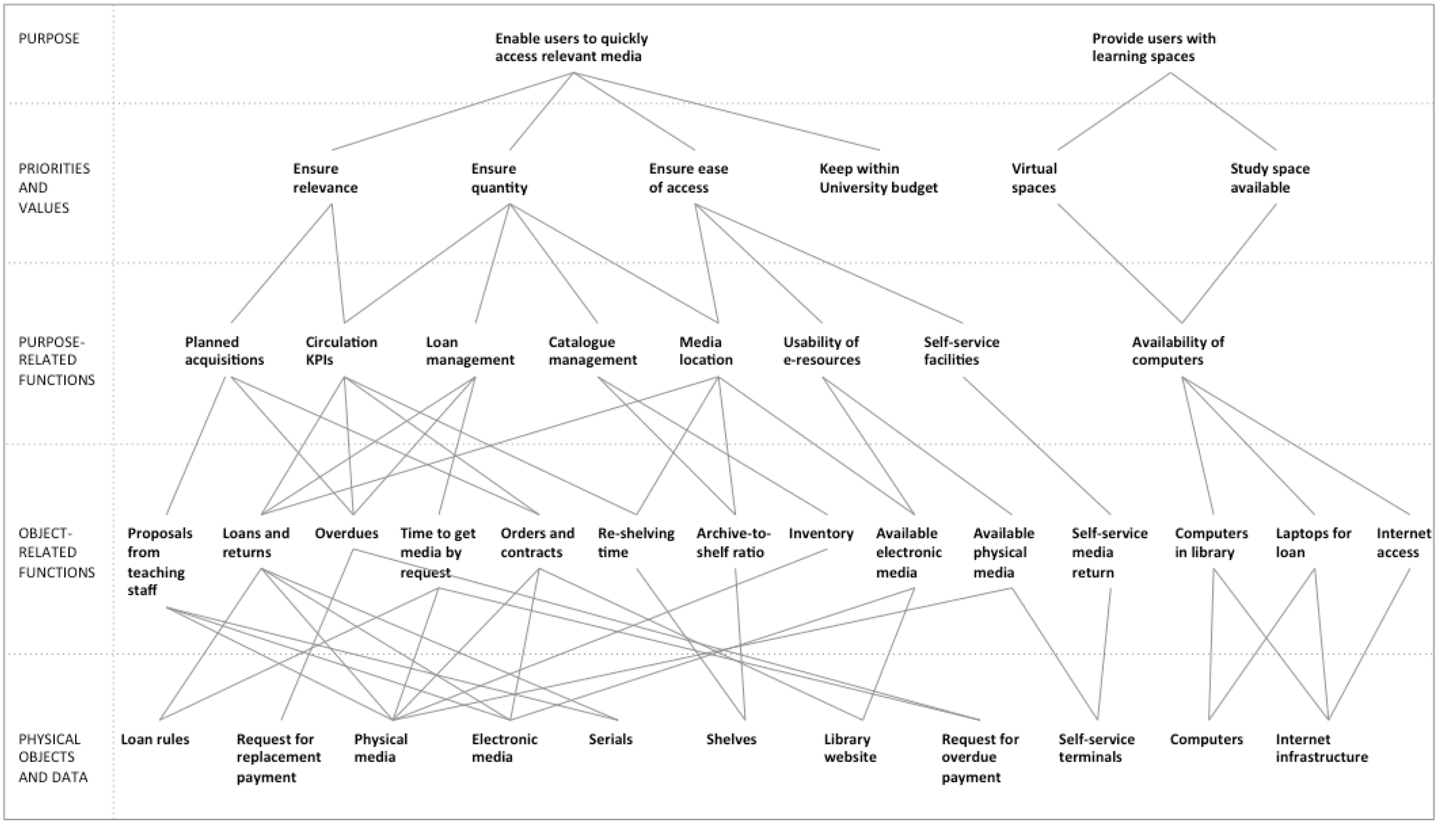

Figure 1: Abstraction Hierarchy of part of a University Library Domain

By themselves, functional relationships are not as useful in providing insights into the reasons for poor performance. However, when these functional relationships are set against the context of system invariants and constraints, they can provide library managers information useful for diagnosis and localization of problems. The design helps library managers detect and diagnose problems and assess the effectiveness of the library's provision of books and services in the context of its library's goals and priorities. Furthermore, when these functional relationships are portrayed over time and visualized by the use of animation, trends and patterns can be detected with relative ease. The design has been implemented in a software demonstrator.

In the following sections, we briefly describe the resulting Abstraction Hierarchy, the key performance relevant functional relationships, the mapping of the functional relationships to the visual elements of the configural display, and a discussion of three example use cases.

METHOD

We conducted a number of iterative in-depth interviews with three senior librarians at a local university. The librarians had significant management expertise and close relationships to scientific work and viewpoints. For the purpose of this study we paid more attention to the more dynamic aspects of library operations, omitting areas such as access to the archives and older research documents, or the relationship of library operations to the financial budgeting processes. We first identified relevant elements and modeled them into the Abstraction Hierarchy (Rasmussen et al., 1994). In further discussions with the librarians, we determined the functional relationships that were key drivers of library performance. In addition, one of our key tasks was to gain access to a data set that could be used in the development of the software prototype. Working with the librarians, we acquired a large set of data records on student book borrowing activities between September 2012 and January 2016. These entries were used to demonstrate how the Risk Map and underlying algorithms handle a realistic volume of data and relational complexity. Personally identifiable data had been anonymized in advance to protect the privacy of individual students. Initial investigations of the data set gave us an understanding of what could be modeled when developing the algorithms for computing the visual representations. This knowledge helped us define real data relationships within the AH.

RESULTS: ABSTRACTION HIERARCHY

Our modeling of the AH led us to identify three sets of overarching goals and priorities: (i) enabling users to access relevant media by ensuring that the media (e.g. books) are relevant, of the right quantities, and that they are easily accessed; (ii) that this access must be met within the constraints of the University budget; and (iii) the provision of adequate learning spaces by creating and managing the availability of these learning spaces.

DESIGNING AN ANALYSIS INSTRUMENT

Identification of 3 Driving Functions of the Domain

For our work, we focus on the goal of ensuring access to relevant media, which can be decomposed into three priorities that drive the performance of the library's operations: ensure *relevance*, *quantity*, and easy *access*. These priorities can be further decomposed to show how librarians will draw on data from organizational processes, such as the books acquisition planning process and how the list of books are determined. Recommendations for the books to be acquired will come through further organizational processes such as proposals from teaching staff which can be cross referenced to shelf holdings; overdue titles as they may suggest that students are holding on to the books despite the fines as they contain material relevant to their study; and the orders and contracts system to ascertain if the books are arriving within the required time frames. For the purposes of this study, we modeled the following as examples of objects of the system: "loan rules", "physical media" (i.e. the books and the number of copies in the collection), and the availability and serviceability of "self-service terminals".

In this way, we can express the relationships between the system purposes, to its priorities that drive system performance, the organizational functions form which we can extract data, and the functions that operate the objects of the system. For example, we can reason whether the lack of availability of required textbooks is likely to be due to applying the wrong loan rules, e.g. 3-hour loan vs 7-day loan, and therefore the demand this places on the quantity of books that need to be available, at a period of time during the semester when the book is needed.

With the help of the AH, the domain objects which contribute to an assessment of the relevance, quantity, and ease of access functions, are identified in the following.

Relevance

According to the domain analysis, recommendations and requests by scientific personnel, as well as reading lists issued for teaching purposes, provide qualitative information about the relevance of catalog entries. Besides these, quantitative figures about the circulation intensity of media can be consulted to calculate a measure for the relevance of library catalog entries. These figures possibly include the average time media is on loan, the number of overdues and requests for non-available media (unfulfilled or fulfilled requests), or even the share of losses of physical media, which, if assumed to be partially caused by theft, also can be an indicator for the relevance of catalog entries. The overall conceptualization of relevance in the analyzed domain is semi-formally summarized in Formula 1.

$$relevance = f\,(\,recommendations,\ requests,\ avg\ time\ on\ loan,\ overdues,\ requests_{placed},\ requests_{fulfilled},\ losses\,)$$

Formula 1: Influential components of a relevance function for library catalog entries

Quantity

The available and demanded quantity of media is the second relevant function for assessing the library's overall status. Its evaluation can be based both on how much media on average is in use, and the total number of media available for a catalog entry in the boundaries of the observed timespan. This way, a measure that combines demand and supply is established. In addition, figures about extensions of capacities or weeding of media in stock can be taken into account, as well as the known numbers of items currently missing. The suggested conceptualization of a quantity function for catalog entries is summarized in a semi-formal way in Formula 2.

$$quantity = f\,(\,media\ on\ average\ in\ use,\ media\ available,\ acquisitions,\ weeding,\ losses_{current},\ losses_{current\ -\ replaceTime}\,)$$

Formula 2: Influential components of a quantity function for library catalog entries

Ease of Access

To characterize the notion of ease of access, data from library facilities that directly provide functionality for loaning and returning media, e.g., self-service kiosks and automatic returns facilities, can serve as a foundation. Also, the behavior of users when it comes to actively requesting media can give hints on how to estimate ease of access for catalog entries. For electronic resources, usage statistics can directly be extracted per catalog entry, especially from data about failed attempts to access resources with contractually limited numbers of parallel users at a time. Formula 3 summarizes these considerations.

$$access = f\,(\,self\text{-}service\ kiosk\ use,\ automatic\ return\ facilities\ use,\ requests_{placed},\ e\text{-}media\ failed\ access\,)$$

Formula 3: Influential components of a function to assess ease of access for library catalog entries

Mapping of the Driving Functions onto a Visual Projection

We transposed the three main driving functions onto the Risk Map. It consists of a 2-dimensional plane onto which catalog entries (e.g. books and other media) managed in the library are projected as dots or clusters of dots. For the purpose of this prototype dots are shown in different "traffic light" colors – red, yellow, and green – representing differing levels of ease of access.

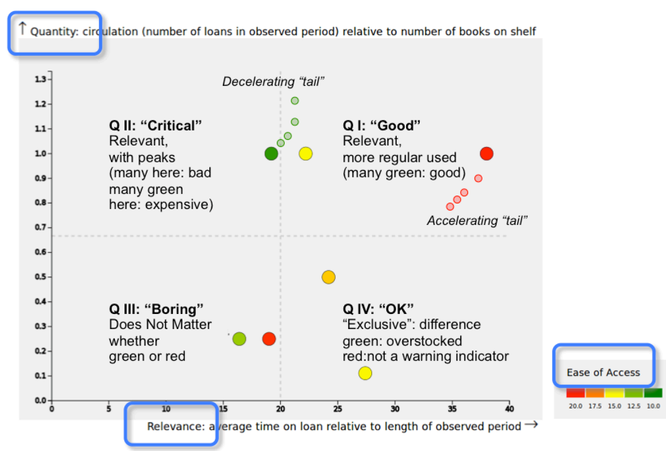

Figure 2: Example of the 2-dimensional dot-plot projection

Each color represents a measure of the ease of access. Recognizing that approx. 10% of men and approx. 1% of women are color blind, we used the primary colors to encode information. Should the opportunity arise to extend this work, additional cues will be included to provide some degree of visual redundancy. Each dot is positioned on the 2-dimensional plane according to the relevance measure (x-axis) and the quantity measure (y-axis). Figure 2 shows an example.

The 2-dimensional projection plane is divided into four quadrants, marking different managerial viewpoints for assessing performance of the domain objects. The quadrants also represent the invariants of the system, such as areas of good and poor system performance.

Quadrant I. This marks an area of the projection plane, in which relevant catalog entries that are available in high media volume are displayed. This is the "success area" of the library. It lies in the inherent interest of the library management to let a high fraction of the overall media stock be represented by catalog entries in this quadrant, and to ensure an easy access (many "green" dots) to these media.

Quadrant II. Catalog entries in this area indicate that the library has high volumes of these books, but are of lesser relevance to the users of the library. The assessment of entries in this quadrant is ambiguous: on the one hand, having high volumes available even of media which is less relevant for users can ensure to keep up a level of easy access even at peak request times. On the other hand, maintaining large stocks of mostly unused media may cause unnecessary cost and hinder success in other areas of the organization.

Quadrant III. Catalog entries that appear in Quadrant III have considerably lower volumes and are of comparably low relevance. The entries in this quadrant thus contribute less to the overall success or failure of the management, and thus may require less attention, also with regard to their ease of access.

Quadrant IV. Entries projected into this quadrant are considered relevant, although possibly not enough copies are available when they are used in high volumes. They form the more exclusive selection of catalog entries of the library. From a management point of view, it is desirable to ensure appropriate ease of access for users in this field. Difficulties in accessing media residing in this quadrant may be an indicator that the actual availability of media is too low and availability should be extended.

The visualization provides several features. By making use of the spatial distribution of dots on the 2-dimensional plane, it is easy to detect catalog entries "at the edge", for example if dots appear at the periphery of the plane. These represent exceptions or outliers. Additionally, this can be supported by a distinctive coloring scheme that marks extreme values with highly saturated red or green tones.

Animated "tails" can be used to represent changes in the positions of the dots over time. Figure 2 shows tails over four time periods. By perceiving animated changes in the positions of dots, it becomes possible to use natural cognitive abilities to extrapolate future critical or desirable situations based on actual data, rather than computing projected trajectories. The separation between each preceding dot in a tail can be used to indicate an increasing (accelerating tail) or decreasing (decelerating tail) rate of change over time. Such animation can also indicate direction of change – towards or away from better or more desirable areas of performance.

While it is possible to assign typical characteristics to entries represented in each of the four quadrants, the visual carriers of meaning in the representation do not suggest a clear-cut categorization of entries in each of the quadrants. Instead, the attribution of characteristics and the interpretation of the situation in relation to the system invariants and constraints, are entirely left to the expert users rather than being enforced through system recommendations.

To allow for a rudimentary drill-down into details, the current prototype shows a textual tooltip with detail information about individual catalog entries when the cursor is held over (hover) the circle. Other options for realizing drilling-down could be realized, such as zooming into the current view, or changing the perspective to another view.

EXAMPLE USE CASES

To illustrate the expressiveness of the Risk Map when animation comes into play, three example use cases in which concrete domain interpretations can be derived from animated visual projections are described next.

Example Use Case 1: "Relax"

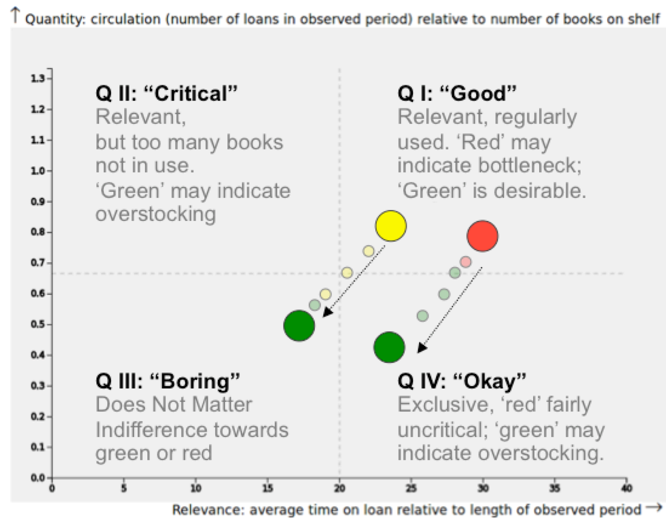

Figure 3: Example Use Case 1 – "Relax"

Example Use Case 2: "Theft?"

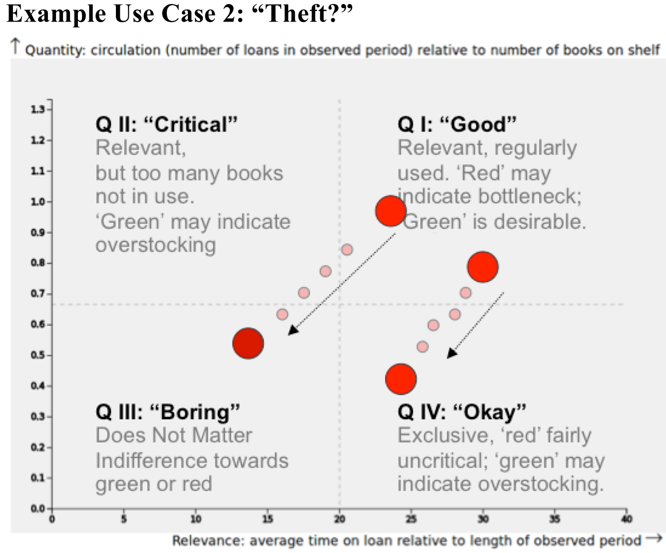

Figure 4: Example Use Case 2 – "Theft?"

Figure 3 shows an example use case in which dots from Quadrant I that initially are colored in red show a movement toward Quadrant III and Quadrant IV, while gradually changing their colors to green. This situation can be interpreted as a relaxation of previously existing bottlenecks and a return to a normal status for the involved catalog entries: the quantities with which media is demanded decrease, which makes them more easily accessible to those users who still consider these media as relevant. A different interpretation results if instead of turning green, dots move from Quadrant I downward over time and remain red. This situation might possibly indicate a loss or theft of physical media, as it reveals a contradictory development between expected availability and actual accessibility. Figure 4 sketches this situation.

Example Use Case 3: "Improvement, but be careful to not exceed capacities"

The situation displayed in Figure 4 indicates a tendency of visualized catalog entries to move from the lower Quadrants III and IV toward the upper Quadrants I and II, independent from their indicated level of ease of access. While in the first place this can be understood as an indicator for a general improvement in terms of usage intensity of the library, the momentum of the movement should be carefully kept in sight, as a too fast increase of the quantitative dimension could result in an over-demand in the future.

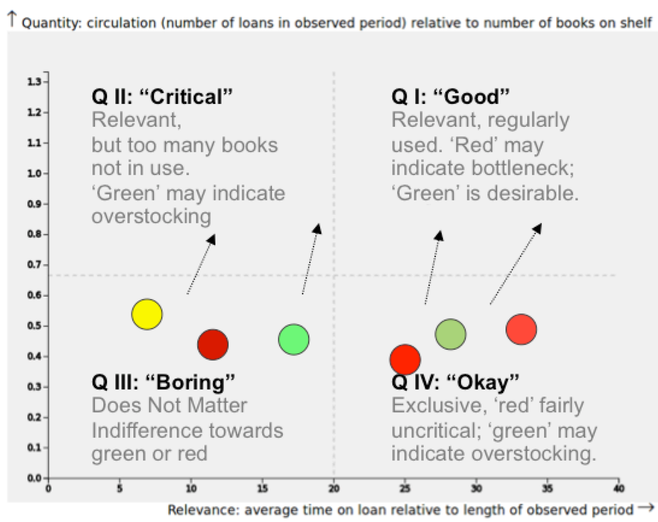

Figure 4: Example Use Case 3 – "Improvement, but be careful"

CONCLUSIONS: SOME REFLECTIONS

We applied cognitive systems engineering and ecological interface design to devise a configural display to address the problem of performance management in a non-typical CSE domain of library management. Following a demonstration and discussions with our three librarians, we made a number of observations about the potential benefits of the Risk Map as applied to library performance management. The Risk Map can:

- Provide cognitive support for the detection of exceptional situations or "outliers" in the management context.
- Enable librarians to extrapolate as-is constellations to predicting future situations, by means of natural tempo-spatial perception rather than computational analysis.
- Make visual constellations assessable in differentiated ways. That means, the representation should be value-neutral and not already propose an evaluation of a displayed situation, which should be left over to the human expert user.
- Enable library managers to observe library performance from different levels of granularity, either globally in its entirety or locally by drilling down into details.

In addition, we had hope to understand how CSE and Ecological Interface Design, or EID (Burns & Hajdukiewicz, 2004), ideas in the creation of configural displays can be adapted and used by those wishing to apply it to the design of business and organization performance information dashboards, especially in the context of big data visual analytics. A number of other observations also come to mind:

- Are functional relationships that drive key organizational performance also Key Performance Indicators (KPIs)?
- The AH can provide Business Process Modeling (BPM) an alternative way of modeling business processes that can link functions and processes directly with system performance.
- Configural displays can potentially work well in non-typical CSE domains, such as in representing business operations, and could provide an alternative and objective way to represent organizational performance.

ACKNOWLEDGEMENTS

We would like to thank librarians Alex Birchall, Kate Webb, Vanessa Hill, Keith Segal and Mark Shilingis, at Middlesex University London for generously sharing with us their time and expertise. We also gratefully acknowledge the opportunities to apply the Risk Map to library management during the *Dagstuhl Seminar* 16191 Fresh Approaches to Business Process Modeling, 8-13 May 2016, Schloss Dagstuhl, Leibniz-Zentrum fur Informatik, Germany.

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