Journal of Operations Management 39-40 (2015) 23–30

Contents lists available at ScienceDirect

Journal of Operations Management

journal homepage: www.elsevier.com/locate/jom

How analytic reasoning style and global thinking relate to understanding stocks and flows

Justin M. Weinhardt [a, *], Rosa Hendijani [a], Jason L. Harman [b], Piers Steel [a], Cleotilde Gonzalez [b]

[a] Haskayne School of Business, University of Calgary, 2500 University Drive-NW, Calgary, AB, Canada
[b] Carnegie Mellon University, Dynamic Decision Making Laboratory, United States

ARTICLE INFO

Article history:
Available online 26 July 2015

Accepted by Daniel R. Guide

Keywords:
Cognitive reflection
Global/local reasoning
Stock-flow failure
Correlation heuristic
Behavioral operations

ABSTRACT

Understanding stock-flow relationships is fundamental to the management of operational systems. In their most basic form, stock-flow systems consist of resources that accumulate and flows that change their level. Managing stock-flow systems is an indispensable part of operations management, including supply chain, inventory, and capacity planning. Previous studies have shown that most people, even experts and well-educated individuals, make persistent errors when inferring the behavior of accumulation (i.e., stock) over time. However, little is known about what individual characteristics make a decision maker better or worse at understanding stock-flows. In this paper, we report the results of investigating the relationship between analytical-intuitive thinking and global-local processing on performance in a simple stock-flow problem.

We find that individuals with an analytical thinking style, rather than an intuitive one, perform significantly better on a stock-flow problem; whereas individuals with a global, rather than a local, thinking style do not necessarily perform better. However, even individuals who exhibit analytical thinking have a poor understanding of stock-flow problems. Analytical thinking may be related to understanding stock and flows, but more work is needed to better understand what cognitive abilities are required to solve these problems.

1. Introduction

Operational systems rely on the basic building blocks of dynamic systems: stocks (accumulation over time), inflows (that increase accumulation), and outflows (that decrease accumulation). Effectively managing dynamic systems, including operational systems, requires a good understanding of how stocks accumulate and deplete as a function of the flows that alter them (Gonzalez and Dutt, 2011; Sterman, 1989a). In fact, understanding stock-flow dynamics is an inseparable part of managing organizational operations for situations including inventory control (Croson and Donohue, 2006; Croson et al., 2014), capacity planning and investment (Sterman, 1989a,b), and new product development (Paich and Sterman, 1993). However, previous studies have shown that humans lack a basic understanding of stock-flow systems, and even highly educated individuals are often unable to solve relatively straightforward stock-flow judgment tasks (e.g., Booth Sweeney and Sterman, 2000; Cronin et al., 2009; Cronin and Gonzalez, 2007; Jensen and Brehmer, 2003; Sterman and Booth Sweeney, 2007). The chronic inability of individuals to answer these dynamic questions led Cronin et al. (2009) to label the phenomenon as the stock-flow failure.

One proposed explanation for the stock-flow failure is that individuals use a pattern matching or correlation heuristic, where they attempt to match the trajectory of the stock with that of the inflow rate (Cronin et al., 2009). In other words, people fail to recognize the causal mutual relationship between stocks and flows in a sense that the stock accumulates (depletes) when the inflow is greater than (less than) the outflow. Instead, they use linear thinking and intuitively assume that the pattern of the stock looks like and highly correlates with the pattern of the inflow or the net flow (inflow minus outflow) at one point in time (Cronin et al., 2009; Dutt and Gonzalez, 2013; Sterman, 2010). Correlational reasoning can have serious implications in operations management decision making. In inventory management, it can cause

* Corresponding author.
E-mail address: justin.weinhardt@haskayne.ucalgary.ca (J.M. Weinhardt).

http://dx.doi.org/10.1016/j.jom.2015.07.003
0272-6963/

suboptimal order placements even in the simplest forms of inventory systems (Bendoly et al., 2010).

The use of the correlation heuristic may also lead to errors in reasoning that have consequential impacts on society, businesses, and everyday life. For example, one of the key issues in the sustainable management of natural resources is the distinction between the stock-flow mechanisms for renewable (e.g., aquifers and lakes) and non-renewable (e.g., oil and fossil fuels) resources (Sterman, 2012). While renewable resources have inflows that can offset their usage, non-renewable resources have no inflow on a human timescale (i.e., they are not replenished if used). To have a sustainable economy, all non-renewable resources need to be substituted by renewable ones (Sterman, 2012). Sterman (2002) outlines how some economists do not have a clear grasp of the distinctive structure of stock-flows for renewable and non-renewable resources. In addition, many people erroneously believe that greenhouse gas concentrations can be stabilized, even given the knowledge that gas emissions are now almost double their removals from the atmosphere (Sterman, 2008). The erroneous belief that stabilizing emissions would quickly resolve climate change problems has resulted in a "wait-and-see" or "go-slow" policy that will bring forth irreversible consequences due to the long lag between external interventions and the climate system's resulting response (Dutt and Gonzalez, 2012; Sterman, 2008).

Unfortunately, studies have shown that the poor performance in simple stock-flow tasks persists regardless of contextual familiarity, changing information displays, and performance feedback (e.g., Booth Sweeney and Sterman, 2000; Brunstein et al., 2010; Cronin et al., 2009; Cronin and Gonzalez, 2007; Jensen and Brehmer, 2003; Sterman and Booth Sweeney, 2007). Not only is stock-flow performance often poor, but we lack an avenue or strategy for improving it. Recent work in operations management (e.g., Bendoly et al., 2010; Bendoly et al., 2006; Cantor and Macdonald, 2009; Croson and Donohue, 2006; Moritz et al., 2013a,b) has emphasized the importance of measuring individual attributes as predictors of performance in different operations management contexts. The goal of the current paper is to investigate known judgment and decision making measures of individual reasoning styles applied to operations management and the stock-flow problem in particular.

2. Stock-flows and operations management

Grossler, Thun, and Milling (2008) proposed that accumulations play a substantial role in operations management, but they are often ignored. Stock-flow processes are widespread in OM (Grossler et al., 2008), and the failure to understand these processes has negative implications in the management of operational systems (Sterman, 1989a,b). For example, in process improvement, understanding the underlying dynamics is critical to sustainable enhancements for organizational processes. Organizational processes act as a stock of resources that can be accumulated through continuous process improvement (Repenning and Sterman, 2001). Time spent on improvement increases the inflow of capability investment, which in turn improves process capability over the long run. Because organizational resources are limited, allocating them to everyday work will leave no time for improvement. Therefore, the stock of process capabilities will deplete over time, resulting in a low quality system with outdated capabilities. This dynamic process is referred to as "capability trap" (Repenning and Sterman, 2002, 2001). It will force workers to shift towards longer hours of work, instead of allocating time to process improvement in order to meet the required production rate. While increasing work hours can temporarily boost the output rate, lack of time spent on process improvement will eventually deplete the stock of quality processes, leading to a spiral of declining capabilities within the organization (Repenning and Sterman, 2002).

In the management of maintenance systems, a clear understanding of the relationship between stocks (i.e., equipment defects) and the related outflows (i.e., elimination of defects through planned maintenance versus reactive maintenance) is similarly important. In fact, a balance between these two outflows is required for the efficient management of maintenance systems. Reactive maintenance tries to fix the defective equipment after a breakdown occurs and return them to work. Planned maintenance, on the other hand, focuses on the proactive repairing of equipment by finding the "latent defects" and fixing them before any breakdown occurs.

Planned maintenance does this through the frequent monitoring of operating equipment (Sterman, 2000). Considering the limited resources of the maintenance department, spending time on reactive maintenance will take up maintenance workers' time with repairing defective equipment, instead of regularly monitoring equipment to prevent the occurrence of future defects. Focusing on defect correction instead of defect prevention leads to a continuous flow of defects that need to be fixed by maintenance workers. This will leave no time and resources for planned maintenance. Nevertheless, traditional maintenance systems often disregard the trade-off between reactive and planned maintenance, which arises primarily from having limited resources in the organizations. Therefore, such systems are swamped by frequent breakdowns and their preventive strategies completely ceased in the end (Grossler et al., 2008).

As illustrated above, understanding accumulation is essential for effective operations management. However, research has shown that operations management experts often fail to conceptualize the concept of accumulation without system dynamic models of their maintenance systems (Repenning and Sterman, 2002, 2001; Sterman, 2000). To understand why some individuals may not understand the concept of accumulation, we turned to the growing body of literature in operations management that focuses on the behavioral factors affecting decision making in the field (Bendoly et al., 2010; Bendoly et al., 2006; Gino and Pisano, 2008).

Specifically, we build on the work that has investigated individual differences regarding reasoning ability (Moritz et al., 2013a).

3. Judgment and decision making in operations management

Researchers using the newsvendor problem have shown that heuristics and biases can negatively influence decision making in operations management. Some examples are the pull-to-center ordering effect (Bolton and Katok, 2008; Schweitzer and Cachon, 2000), demand chasing heuristic (Bostian et al., 2008), and the demand estimation bias (Feiler et al., 2013). Given that heuristics can be a source of decision-making errors, we identify two individual differences that should be influential in diminishing or managing the effects of heuristics in operations management (Moritz et al., 2013a). We examine how analytical versus intuitive reasoning and global versus local processing relates to performance in a stock-flow task.

3.1. Analytic reasoning style

Individuals often rely on intuitive reasoning over analytical reasoning, leading to a number of judgment and decision making errors (Frederick, 2005; Kahneman and Frederick, 2002; Stanovich, 2009). Intuitive reasoning is characterized by spontaneous and emotional decisions with little conscious deliberation. Analytical reasoning, on the other hand, is characterized by deliberate and