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REVIEW

Behavioral Operations Management: A Review of the Field

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ABSTRACT

Behavioral operations management (BOM) is one of the new areas in operations management. In the past 12 years, the field has made huge progress and researchers have become interested in this new perspective to solving operational problems. BOM is now one of the major subfields of operations management. In this paper, we examine and categorize areas of BOM based on the mainstream literature. Key areas include behavioral issues in new product development and project management, quality management, production management, inventory management, service operations, and forecasting. Studies in each area are divided into three subcategories, including OM context, individual attributes, heuristics, and biases, and individual differences. In OM context category, feedback and reward, training, work monitoring, teamwork and group decision making, goal setting, task assignment, and flexibility are among the main topics. In individual attributes, heuristics, and biases category, sunk cost effect and escalation of commitment, endowment effect, overprecision bias, planning fallacy, pull-to-center effect, anchoring and insufficient adjustment, and misperceptions of feedback are mainly discussed. In individual differences, analytic thinking and system thinking are mainly studied. New areas for research are suggested in each related section and are summarized in future directions and conclusion sections. In contexts such as new product development, project management, and inventory management, a shift to finding solution to performance improvement is beneficial instead of focusing on heuristics and biases and considering them as a deficiency in human decision making. Regarding individual differences category, a shift toward attributes other than cognitive abilities, such as global processing, creative thinking, and design thinking are recommended.

1. Introduction

Humans play a significant role in the development and implementation of operational systems. Behavioral operations management (BOM) is a branch of operations management that focuses on the role of humans in operational settings. After 12 years of burgeoning research, BOM has now become one of the major subfields of operations management. It has become a multi-disciplinary area. Theories and research methods from other areas, including behavioral economics, organizational behavior, behavioral decision making, system dynamics, cognitive psychology, and social psychology have influenced the development of this subfield [1, 2, 3].

BOM started formally in 2006. In this year, Journal of Operations Management assigned a special issue to

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behavioral operations management [4]. This special issue coincided with the first behavioral operations conference in the US. Since that time, many journals in operations management have allocated one of their areas to behavioral operations management [5, 2, 6] and operations management conferences have assigned a track to behavioral operations. In addition, behavioral operations conference has been held internationally every year. This area has received an escalating attention from researchers in operations management and other related disciplines around the world.

In this paper, we review the literature on behavioral operations management in order to inform interested researchers of the key areas and the potential areas for future research. In the following sections, we will first provide a definition of behavioral operations management and clarify its boundaries. Then, we will discuss the areas and sub-areas within behavioral operations management [5]. We conclude our discussion by providing areas for future research.

2. Behavioral Operations Management Definition

As the field of BOM has expanded in recent years, it is important to provide a definition for it and determine what differentiates its research from other disciplines. Researchers in any field need to define the focus of their own research in order to create a common understanding among scholars in the discipline [7, 8]. Several definitions have been provided for BOM in the literature [9, 5, 3]. Behavioral operations management is defined as a field of study that focuses on the behavior of individuals within operational contexts that deviate from rationality [5]. In other words, for a research to be considered in BOM area, it must have components of individual behavior within an operational context, the type of behavior that does not fall within the frameworks of hyper-rationality.

Based on this definition, BOM includes studies that address problems in operational contexts, deal with non-hyper rational actors, and their level of analysis is at the individual or group level. Operations management contexts have distinct challenges and complexities that distinguish them from general contexts addressed in other fields such as organizational behavior and social and cognitive psychology. The type of research in BOM is not based on the assumptions of hyper-rationality. They make the assumption that motivation and behavior are not shaped solely by self-interest and decision making is not always conscious and well-informed. In addition, the level of analysis is mainly individuals or groups of individuals who deal with operations management problems.

3. Areas of Research in Behavioral Operations

Behavioral operations management comprises many areas. Based on a categorization of BOM studies [5], the main subject areas include: supply chain management (27%), new product development and project management (17%), quality management (11%), production management (10%), inventory management (8%), service management (7%), conceptual studies (7%), forecasting (4%), and others (9%). In this paper, we focus on key areas in behavioral operations management, including, new product development and project management, quality management, production management, inventory management, service management, and forecasting. Studies in each of these areas are examined and discussed in the following sections. Behavioral topics in supply chain management have significantly grown in the past few years and have created a separate area called behavioral supply chain management [10, 11]. Due to the length limitations, we do not discuss these topics in this paper.

The categorization and literature related to each area are determined based on the review papers in BOM literature. These review papers used in this study and their discussed areas are listed in the table 1. Following previous reviews, only empirical studies were included [12]. The review papers have mentioned several subareas. However, in one recent study on clustering [1], the authors found two clusters around inventory management problems, including newsvendor and bullwhip and inventory optimization clusters. The rest of the areas had no clusters around them. Conceptual and analytical studies were excluded since BOM mainly attempts to use empirical research methods especially experimental research to differentiate it from the traditional research in the field of OM. One of the reviews focused on experimental studies only [12]. Another review of the literature showed that 94% of the studies in BOM used empirical research methods and 43% used experimental ones [5].

In addition to considering the studies mentioned in the review papers, we actively searched the literature to find BOM papers published in each of the subareas in top academic journals in management and psychology in recent years. We searched for the BOM papers in several search engines including Google Scholar, Web of Science, PsychInfo, and Scopus using key words related to behavioral operations and the related subareas. We used a combination of search terms including behavioral/behavioural, new product development, project management, inventory

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management, quality, production, newsvendor problem, service, queueing, waiting lines, forecasting, judgmental forecasting, and behavioral operations. The final list included 73 papers that had empirically tested behavioral issues in each of the main categories.

Based on the review of the literature, we categorized the subareas in each of the main areas into two subcategories of operations management context and individual characteristics. Individual characteristics were then divided into two categories of individual attributes, heuristics and biases and individual differences. The behavioral issues in OM arise from the interaction between operational contexts and individuals that work within these contexts. Therefore, studies in BOM literature have examined the problems either from the standpoint of the characteristics of the OM context or the individuals within the related context. Studies in the OM context category focus on the context settings such as design of operational settings, motivational mechanisms, performance feedback, goal setting, and other contextual factors that influence the behavior of individuals. Studies in the individual characteristics category can be divided into two subcategories. One subcategory focuses on human attributes, heuristics, and biases and the other focuses on individual differences and their effect on operations management decisions. The review studies have also mainly viewed the literature from either of these two standpoints. For example, in one study, researchers examined the individual heuristics and biases that influence decision making in the OM context [13]. Similarly, another review categorized behavioral issues in OM into four categories of cognitive psychology, social psychology, group dynamics, and system dynamics, putting the emphasis on individual and group characteristics and their effect on decision making in the OM context [14]. On the other hand, other literature reviews [12, 15] mainly focus on the effect of operational context and its settings on the performance of individuals and groups working within these contexts. Factors such as individual versus group decision making and goal setting, independent versus interdependent task assignment, motivational mechanisms, and feedback type are among the ones that are addressed in these studies.

Table 1. Review and conceptual studies

Reference No.	New product development and project management	Quality management	Production management	Inventory management	Service management	Forecasting
[1]				x		
[5]	x	x	x	x	x	x
[12]	x	x	x	x		x
[13]	x	x		x	x	x
[14]	x	x	x	x	x	x
[15]		x	x	x	x	
[126]	x		x	x		

In table 2, the references related to each of the subcategories are presented. Areas with no references are the ones that have received the little attention and therefore, have the potential for future research. In table 3, the topics in each subcategory are presented. The topics in normal font include the ones that have been addressed in the past literature thorough empirical studies. The italicized topics include studies that have not been addressed empirically but have the potential for future research.

3.1 New Product Development and Project Management

One of the behavioral areas in operations management is new product development. Since problems in new product development are generally of a project nature, the problems and challenges in this area are often considered in the same category as project management problems [5]. Due to the high speed and flexibility required in project management and new product development, attention to behavioral issues are of great importance.

3.2 Operations Management Context

A series of studies examined the effect of feedback on performance in new product development projects. In one study, researchers examined the effect of relative versus absolute performance evaluation [16]. In relative performance evaluation, the performance of managers was compared with that of a peer group. In contrast, in absolute performance evaluation, the performance was assessed individually based on pre-specified performance standards. According to this study, relative performance evaluation resulted in better decision making among managers in new product development projects. Relative performance appraisals could increase managers' inclination to choose riskier capital investment projects, especially for firms in high-risk technological/economic conditions. In another study, the effect of cognitive feedback, cognitive feed-forward, and outcome feedback on performance was examined in the context of a simulated project on software development [17]. Participants played the role of project managers and made a series of decisions related to staffing over the life of the project. Different types of feedback were given to participants. The results showed that participants who received cognitive feedback performed best, followed by those who received cognitive feed-forward.

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In contrast, those who received outcome feedback did not perform well compared to others [17]. Other studies examined the effect of training on attitude towards divergent thinking among manufacturing engineers in problems related to new product development [18]. Results of the study showed that training had a positive effect on attitude towards divergent thinking in problem solving in new product problems.

Other studies in this line examined the effect of individual versus group goal setting and decision making on performance. In one study, researchers examined the effect of group versus individual goals on performance in new product development projects. They found that when collaboration was required and the tasks were inter-dependent, group goals were more effective compared to individual goals and resulted in better performance outcomes [19]. Group decision making compared to individual decision making can improve the quality of decision making and performance in different stages of new product development and project management, including initial investment [20] and later stages of a project [21]. In addition, virtual teams performed better than face-to-face teams in product development projects [21].

Review of the literature on behavioral new product development shows that studies have been mainly conducted in 90s and early 20s. These results suggest that new studies on behavioral issues in new product development are required to shed light on different aspects of OM context and their interaction with human behavior in this context.

Table 2. Studies included in the review

Area	OM Context	Individual Attributes, Heuristics and Biases	Individual Differences
New product development and project management	[16], [17], [18], [19], [20], [21]	[22], [23], [27], [29], [31], [32]	[33]
Quality management and control	[42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52]	[52]	[56], [57]
Production management	[52], [58], [59], [60], [61], [62], [64], [65], [66], [67], [68], [69], [70]		
Inventory management	[71], [72], [73], [81]	[72], [73], [74], [76], [77], [78], [79], [80], [81], [82], [86], [87], [88]	[34], [35], [36], [89]
Service management	[93], [94], [95], [96], [97], [98], [99], [103], [104]	[105]	
Forecasting	[37], [79], [116], [117]	[37], [79]	[37]

3.3 Individual Attributes, Heuristics, and Biases

Sunk cost effect or escalation commitment is one of the biases that have been widely discussed in the new product development and project management literature [12, 14]. It has a significant impact on allocation of resources to new product development and other types of projects. This bias leads individuals to allocate additional resources to projects, depending on the amount of money that has already been invested in these projects [22]. Higher amounts of initial investment result in higher likelihood of future investments even in situations where the project is threatened to be terminated. However, the effect has proved to be mitigated when sunk cost and negative feedback simultaneously occurred [23]. It was found that as the negative feedback increased, the likelihood of continuing the project decreased.

Sunk cost effect is linked with other types of decision making biases, including endowment effect, change resistance, and status quo bias which are the result of an underlying behavior referred to as loss aversion in the decision making literature [24]. Endowment effect refers to individuals' tendency to give higher values to things that belong to them and lower values to things that do not belong to them or require them to change their acts and behaviors. Change resistance and status quo bias are related to the individuals' tendency to resist change. People generally avoid changes even the positive ones and prefer to stay in their current conditions [25, 26]. These biases are frequent in new product development and project management. In the context of project management, these biases lead people to generally give higher values to the projects to which they are committed and have already invested compared to other projects. In one study, managers who had started a project were less likely to accept its poor performance, were generally more committed to the project, and were more likely to continue investing when it was more reasonable to stop the project, compared to those who later assumed management of the project [27].

Overprecision bias is another bias that influences the estimation of project duration. Previous studies have shown that individuals generally indicate very tight time intervals when asked to estimate the length of a project. This bias is mainly due to the fact that individuals generally underestimate the variance inherent in different phenomena [28]. In one study, researchers asked participants to estimate the time required to complete a software engineering project. The results showed that the participants systematically predicted too tight estimates of the project time duration [29]. In fact, more than half of the actual outcomes fell in the 1% tail of the estimated distributions.

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Table 3. Areas of research

Area	OM Context	Individual Attributes, Heuristics, and Biases	Individual Differences
New product development and project management	• Feedback • Performance evaluation • Training • Group vs. individual goal setting • Group vs. individual decision making	• Sunk cost effect and escalation of commitment, • Endowment effect, change resistance, and status quo bias, • Overprecision bias • Planning fallacy and hyperbolic discounting • Misperceptions of feedback	• System thinking • *Cognitive ability and analytical thinking* • *Global information processing* • *Intuitive thinking* • *Design thinking*
Quality management and control	• Feedback • Performance evaluation and control • Work monitoring • Forced standards • Work sharing • Training • Team work, cross training, and work flexibility	• *Attribution and blame error* • *Confirmation bias* • Stress and fatigue • *Law of small numbers* • *Illusion of control* •	• Cognitive ability • Personality traits such as openness to experience and conscientiousness • Risk attitude • Ambiguity tolerance • *Stock-flow understanding*
Production management	• Performance monitoring • Feedback • Work interruption • Reward and task interdependence • Goal setting • Work/task organization • Work pace • Inventory level	• *Law of small numbers* • *Confirmation bias* • *Sunk cost fallacy* • *Anchoring and insufficient adjustment*	• *Cognitive ability and analytical thinking* • *Global information processing* • *Stock-flow understanding*
Inventory management	• Motivational mechanisms such as rewards • Feedback • Learning • Goals • *Inventory separation*	• Demand-chasing heuristic • Anchoring and insufficient adjustment • Over-precision bias • Pull-to-center effect • Bounded rationality • *Availability heuristic* • *Risk attitude* • *Procrastination* • *Inconsistency bias*	• Cognitive ability and analytical thinking • Global information processing • *Stock-flow understanding*
Service management	• Service and wait line design • Queue structure, server pooling, and cross training • Task interdependence • Feedback saliency • Payment schemes	• Experiencing vs. remembering self • *Emotion* • *Trust* • *Choice* • *Anchoring and insufficient adjustment*	• *Cognitive ability and analytical thinking* • *Global information processing*
Forecasting	• Collaborative forecasting • Decision making speed	• Over-reaction and under-reaction to error • Censorship bias	• Cognitive ability and analytical thinking • *Global information processing* • *System thinking* • *Stock-flow understanding*

Note: Areas with italicized font have not been empirically tested in the literature.

The study showed that overprecision bias was not reduced by task decomposition, changing the wording or order of questions, or estimation training. However, the study showed that inducing participants to provide extreme lower and upper plausible time limits, significantly decreased overprecision bias and resulted in more accurate time estimates [29]. Overprecision bias has implications in other OM areas as well, such as inventory management and forecasting. These will be discussed in the related sections.

Another common bias is planning fallacy, which is the systematic tendency to underestimate the amount of time required to complete a project. This fallacy results in the underestimation of time and resources that are required to complete a project. It is related to hyperbolic discounting [30]. Hyperbolic discounting reflects the tendency to mentally value present significantly higher than any time in the future. In other words, individuals have an inclination to give higher weights to what happens now compared to any time in the future. Immediate costs/rewards are much more salient in one's mind, resulting in decisions that provide high instant satisfaction and low long-term ones. Planning fallacy and hyperbolic discounting have implications on decision making in project management and new product development, due to the inter-temporal nature of decision making in these contexts. Decisions on project

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scheduling and financing and decisions on continuing or terminating new product development projects are some examples. They result in delays in projects even in relatively stable conditions. Motivational mechanisms are suggested as a method to help project managers reduce these biases and improve their estimation accuracy [31].

In another study, researchers found that misperceptions of feedback in the form of inadequate consideration for important feedback, time delays, and system nonlinearities had a significant negative effect on performance in a new product development task [32]. The performance was poor even when participants repeated the game in several rounds.

3.4 Individual Differences

Individual differences have not been significantly studied in project management and new product development. One study examined the effect of system dynamic understanding on project management [33]. System dynamic understanding is one aspect of system thinking which focuses on the ability to understand the dynamics of systems and their related features such as feedback and delays. The results showed that system dynamic understanding and the similarity between individuals' understanding and that of their team members had a significant positive effect on psychological safety and quality of information sharing in project teams which in turn influenced project performance.

Individual differences in analytical thinking and global information processing are some potential areas for future research. Previous studies have examined the effect of these two individual differences on performance in OM contexts, such as stock-flow problems [34, 35], inventory management [36], and forecasting [37]. These individual differences might have the potential to reduce decision making biases such as overprecision bias, planning fallacy, and hyperbolic discounting. Analytical thinking style can help people analyze a problem from a more rational standpoint and better estimate the required times for different stages of a project. Global information processing compared to local processing allows individuals to look at the big picture of the project and consider all the factors that might influence the completion time of the project. Thus, these two factors might help in decreasing cognitive biases in decision making and result in a more accurate estimation of the length of a project. Other individual differences such as intuitive thinking [38] and design thinking [39, 40] can also be considered as individual differences that can help in the design and development of new products. These characteristics have the potential to help in finding simple, familiar and intuitive solutions to problems in the area of new product design and development.

4. Quality Management and Control

Behavioral studies in quality management and control have long been conducted in operations management. Influencing the behavior of individuals including organizational members and customers has a pivotal role in implementing quality programs such as Six Sigma and Total Quality Management [9]. Thus, behavioral issues are highly relevant to the design and implementation of quality management programs in organizations.

4.1 Operations Management Context

Feedback can have a significant effect on quality control. It can improve quality by increasing the level of self-inspection [41] and mistake proofing [42]. One study examined the effect of different types of feedback (2 types: immediate versus delayed x 2 types: self-paced versus machine-paced) on performance in a quality control task. Error detection accuracy in quality control was higher in self-paced compared to machine-paced and in immediate compared to delayed type of feedback [43].

Work monitoring have also been examined in some studies. On study examined the effect of management monitoring and control on performance in a work setting in which individuals are free to manage multiple tasks [44]. While work monitoring had positive effects on the quality of monitored tasks, it had negative effects on the quality of non-monitored tasks. Another study showed that delaying monitoring events in error identification tasks resulted in better performance [45]. This was regardless of the type of information and guidance that could be provided by the monitoring system.

The effect of process control on perception of quality was tested in another study. The results showed that process control can have a positive effect on individual's perception of process quality [46]. Experiments done by researchers in this study indicate that individuals prefer processes with higher levels of control to the ones with lower levels of control. The role of training and decision support systems on assessment of quality control have also been studied. The results showed that when the type of training was matched with individual's prior knowledge and mental model, it was effective and resulted in better learning and more accurate assessments among individuals [47]. Teamwork, cross training and flexible work are also mentioned in the literature as methods to decrease error and improve the quality of operational processes [48, 49, 50, 51].

In another study, researchers conducted a series of experimental studies to examine the effect of different con-

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textual and behavioral factors on quality [52]. The results supported the negative effect of forced standards and individuals' stress and fatigue on process quality. In addition, the study highlighted the positive effect of work sharing on process quality. This study also focuses on resistance to change and its sources in process improvement programs.

4.2 Individual Attributes, Heuristics, and Biases

One of the main decision making biases in the quality management context is related to attribution and blame error. Process quality is often assessed with the level of statistical control. All processes have variation and a large percentage of the variation is random [53]. Managers, however, often have the implicit assumption that the process outcomes are deterministic or have an insignificant level of variation. Such mental assumptions lead them to look for causes in the form of finding someone to blame when processes produce defective outcomes. Blame attribution mostly occurs without considering the possibility that the defects may be the result of the random variation inherent in the process. In psychology, this error is called fundamental attribution error [54]. It leads individuals to look for someone to blame without considering the random nature of the processes. The mistaken assumption that every variation has an assignable cause leads to process tampering. That is, process operators and managers intervene with the processes and modify them when they should do nothing [53, 55].

Studies have shown that statistical process control techniques can help in identifying and separating common cause variation from special cause variation and avoid their related problems [53]. Distinguishing these two types of variation can decrease the level of process tampering and help in correctly identifying special cause variation which need immediate care and attention in order to avoid its occurrence in the future.

Other types of decision making biases can also influence quality management. Confirmation bias can influence the acquisition of information related to quality management and control. It refers to the individuals' tendency to search for information that satisfies their perspective or hypothesis. In quality management, this bias can result in judging the quality of products and services based on the positive reviews from satisfied customers and disregard the reviews from dissatisfied customers [13]. Law of small numbers is another heuristic that can influence decision making in quality management. This heuristic refers to the individuals' tendency to consider small samples as representative of the larger population from which they are obtained. It will lead in mistaken interpretation of data collected from customers in market research or in system tests in statistical quality control. Illusion of control is another bias that leads people to believe that they have control over or can impact the systems or their outcomes [13]. In quality management, illusion of control may force individuals to believe they can influence the variation in processes and therefore, give rise to acts of tampering. As mentioned above, in the case of common cause or intrinsic variation, this behavior can result in interference with the system when the system is in fact normally functioning.

4.3 Individual Differences

Individual differences have an effect on quality control training programs. In one experimental study, researchers found that individual characteristics including cognitive ability, openness to experience, and conscientiousness influenced the effectiveness of error training programs. Participants were randomly assigned to three conditions of control, error encouragement, and error avoidance. The results showed that cognitive abilities and personality traits influenced the effectiveness of training program. Participants who were high on cognitive ability or openness to experience benefited more from error encouragement training programs [56]. In another study, researchers examined the effect of attitude towards risk and tolerance for ambiguity on sample size decision in quality control check [57]. The effect of these attitudes was tested under different levels of risk and ambiguity. The results showed that individuals' attitude towards risk and ambiguity influenced sample size selection. In addition, participants with higher levels of risk and ambiguity tolerance preferred smaller sample sizes and had higher confidence in their decisions even under high risk and ambiguity conditions.

5. Production Management

Production management is one of the main areas in operations management. Behavioral issues play an important role in production management.

5.1 Operations Management Context

Context characteristics such as feedback [58, 59, 60], work interruption [60], goals [61, 62], task interdependence [62, 63, 64, 65], work/task organization [52, 66], work pace [60], inventory level [67], and performance monitoring [68] have been the focus of behavioral studies in production management systems. These studies show that task performance in production systems is dependent on the OM context and these factors can influence performance of individuals and groups in different ways. In one study, performance monitoring proved to have a positive effect on performance among highly skilled workers [68]. Another study

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on feedback showed that team feedback influenced the level of reported collaboration and civic virtues among team members. Groups that received positive feedback reported significantly higher levels of team collaboration and civic virtues compared to groups that received negative feedback [58]. In production lines, performance feedback decreased average processing time in total and among fast workers, indicating improvement in performance of operational systems [60]. Similarly, in another study, workers increased their speed when they felt they were the cause of delay in the production line [69]. The speed of coworkers acted as a feedback which influenced individual's performance. In addition, reward interdependence resulted in the formation of productivity norms among coworkers [69]. Work interruptions, on the other hand, increased processing time, indicating that work interruptions can result in significant productivity loss among workers [69]. In another study, researchers examined the effect of different types of feedback on productivity and performance of workers in an IT-based system for credit card applications [70]. The results show that direct negative feedback results in performance improvement, while direct positive feedback does not significantly improve performance. In addition, indirect negative feedback decreases productivity. But, indirect positive feedback does not influence it.

Different aspects of goal setting also influenced performance as examined in several studies. One study found that goal content (quantity vs. quality) influenced work processes while goal form (gradually difficult vs. fixed and difficult) did not influence processes or performance outcomes [61]. Process-related goals resulted in more process changes but resulted in lower quality performance compared to outcome goals. In addition, outcome goals had a delayed effect on performance. Another study found that goal type (no specified goals, individual goals, and group goals) interacted with monetary incentives and type of production system (push versus pull) [62]. Group goals used in a pull production system increased productivity compared to a push system with no specified goals. Task interdependence and goal setting had an interaction effect on motivation towards the task [64]. Work organization can also influence performance. One study examined the effect of work organization in the form of the work flow policy used in production lines [66]. The results of this study showed that different work flow policies influenced both between-worker variability (i.e., heterogeneity) and within-worker variability which in turn, influenced performance. In particular, work-sharing policy increased heterogeneity and worker variability. While, fixed assignment policy decreased them.

Inventory buffer level also influences the performance of workers in production systems. It has been used in production lines to avoid variation in production speed in different work stations and decrease the issue of blocking and starving in production systems [15]. However, behavioral studies show that when the inventory buffer is low or is completely eliminated, workers change their speed in a way that the congestion and long lines of work-in-process items is prevented. In other words, the elimination or reduction of buffer results in higher coordination among workers and increase in the pace of low-speed workstations. This will automatically prevent the occurrence of congestion or idle time in production systems. In two studies, researchers found that the speed of work in low-inventory production lines was higher than that of high-speed production lines. The increase in speed was to the level that it covered the cost of blocking and starving in such lines [62, 69].

Behavioral studies in production systems as explained above indicates the existence of a wide variety of studies on the effect of different context characteristics on performance of individuals. However, the number of studies in this line have declined in recent years. It would be worthwhile to conduct more recent studies to extend this line of research in behavioral operations.

5.2 Individual Attributes, Heuristics, and Biases

Regarding individual attributes, heuristics and biases, empirical studies were not found in the literature. However, several heuristics and biases, such as the law of small numbers, confirmation bias, sunk cost fallacy, and anchoring and insufficient adjustment could potentially influence performance in production management systems [13]. The law of small numbers can lead decision makers to make erroneous decisions regarding the production of different products based on a small sample of sales data or customer feedback. Similarly, confirmation bias can lead decision makers to consider and interpret the trends in production of different types of products based on their own prior beliefs. The sunk cost fallacy may force individuals to continue in-house production or outsourcing some activities even when the current situation does not seem beneficial [13]. Anchoring and insufficient adjustment can force decision makers to anchor their production level to the average demand in previous periods disregarding the level of standard deviation of the demand distribution. Since heuristics and biases can significantly influence decision making in different OM context, it is suggested that more studies focus on heuristics and biases in production management systems.

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5.3 Individual Differences

Similar to heuristics and biases, individual differences have not been specifically studied in the production management context. As mentioned before, individual differences such as analytical thinking style and global information processing have been proved to influence performance in other OM areas such as stock-flow problems, inventory management and forecasting. It is worthwhile to examine the effect of these individual differences on performance in production management context as well. There is a possibility that these individual differences influence performance in this context as well.

6. Inventory Management

Inventory management is one of the areas that has been studied widely from a behavioral perspective. In this section, we will review and discuss three common areas in behavioral inventory management.

6.1 Operations Management Context

In one experimental study, researchers examined the effect of different motivational mechanisms on performance in inventory audits [71]. They examined the effect of rewards that were based on single or multiple goals on performance in inventory management decisions. The authors also examined the effect of learning, feedback, and goal adjustment on performance of individuals in a repeated inventory management system [12]. The effect of feedback and learning on performance was also studied in other inventory management experiments. In one study, incorporation of experience and feedback had a significant positive effect on optimal ordering in inventory management [72]. In another study, however, feedback and learning did not improve performance [73].

In a conceptual study, researchers suggested that separating different types of inventory such as cycle inventory and safety stock can result in better management of each of these inventories [15]. This method can be beneficial because each inventory has its own purposes and sources of variability. Assigning separate inventory managers to each of them can help in better examination of how these sources of variability have been addressed by their managers [15]. This idea is interesting to be tested empirically in future studies.

6.2 Individual Attributes, Heuristics, and Biases

Heuristics and biases have been studied in both single-echelon and multi-echelon inventory management. Single-echelon inventory management system mainly focuses on the newsvendor problem [74, 75]. Newsvendor problem defines the problem of a person who should sell his/her products within a certain time period, facing demand uncertainty. The seller should decide how much to order based on his/her prediction of demand. Ordering decision should be made prior to the beginning of the period and cannot be changed once the demand occurs. The challenge in the newsvendor problem is to find the optimal ordering point where the total cost of under-ordering and over-ordering is minimized.

Even though there is an optimal ordering solution in the newsvendor problem, decision makers systematically deviate from it. As one study shows, individuals tend to order above the optimal solution for low-margin products and bellow it for the high-margin ones [73]. Experimental studies highlight several behavioral factors, including the tendency to reduce ex-post inventory error (i.e., demand-chasing heuristic) [76] and anchoring and insufficient adjustment [73]. Demand chasing heuristic causes one to use the demand at the previous period as the measure for the next period instead of looking at the general pattern of the demand distribution. Anchoring and insufficient adjustment causes one to anchor his/her order to a predetermined value (usually the mean demand) and insufficiently adjust it based on the variance to reach the optimal level.

Other biases related to the newsvendor problem include: over-precision bias [74, 77] and pull-to-center effect [72, 76, 78, 79, 80]. Overprecision bias causes one to underestimate the variance in the demand distribution and therefore, make errors in their ordering due to lack of attention to the inherent variance in the demand distribution. Pull-to-center effect leads the individual to anchor his/her ordering level for a period close to the mean and insufficiently adjust it based on the variance in demand distribution to reach the optimal ordering level. Pull-to-center effect results in ordering levels that are close to the mean and neglect or underestimate the variance of the demand distribution. In one study, researchers found that overprecision bias had a significant effect on performance in the newsvendor problem [81]. The bias had a high correlation with order bias and predicted one third of the ordering mistakes. Learning and other inventory dynamics did not decrease overprecision bias. However, the authors used an intervention in their second experiment, that significantly reduced this bias. Apart from different types of biases, one study examines the role of bounded rationality on decision making error in the newsvendor problem [82].

Behavioral studies on multi-echelon inventory management systems have mainly focused on the reasons behind variation in supply chain and the occurrence of the bullwhip effect phenomenon. Bullwhip effect refers

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to the increase in the variation of orders as one moves up the supply chain [83]. This effect leads to forecasting errors, product shortage, price fluctuation, high inventory levels, low capacity utilization, and finally low quality [84]. Some of the operational reasons of bullwhip effect are order synchronization, batching, information uncertainty, delays, price discounts and promotions, and shortage gaming [85]. However, behavioral studies show that even after the operational causes of the bullwhip effect are removed, it still remains due to behavioral reasons. One study found that underweighting the supply line of unfilled orders was a systematic bias that contributed to bullwhip effect [86]. Another study replicated these results and extended them to stationary demand distribution and conditions where operational causes were removed [87]. Bullwhip effect remained even when operational causes and demand uncertainty were eliminated [88]. Another experimental study found that bounded rationality in the form of incomplete knowledge can result in bullwhip effect even when no biases are present [82].

Other heuristics and biases can also influence decision making in inventory management systems that have not been previously studied in the context of inventory management. Availability heuristic refers to one's tendency to judge the likelihood or frequency of an event based on the ease with which the event can be remembered. In inventory management, this heuristic can influence risk perceptions when making ordering decisions [13]. An individual might overestimate the risk of inventory overstock or understock for a particular product based on the availability of a similar event in his/her mind. This can in turn result in errors in inventory management decisions. Procrastination is another individual characteristic that can influence inventory management. Procrastination can lead inventory managers not to update the inventory management policy which results in many overstock or understock conditions [13]. Inconsistency bias refers to one's inability to judge consistently in repetitive cases or events. In inventory management, this bias leads inventory managers to change their inventory policies/rules when making identical ordering decisions in different time periods [13].

6.3 Individual Differences

One empirical study examined the effect of thinking style (rational versus intuitive) and information processing style (global versus local) on stock-flow understanding [35]. Inventories are one example of stock-flow systems. Raw materials, work-in-process, and finished goods come into the inventory (i.e., inflow) from one side and items picked up from inventory go out of it (i.e., outflow) from the other side. The results of this study showed that rational thinking style had a significant positive effect on performance in stock-flow problems. In another study, researchers found that global compared to local information processing had a significant positive effect on stock-flow understanding [34].

Other studies examined the effect of rational/intuitive thinking style on ordering error in single-echelon [36] and multi-echelon [89] inventory systems. These studies showed that rational compared to intuitive thinking style resulted in better ordering decisions and lower levels of error.

7. Service Operations

Service management is another area in operations management. Due to the increasing percentage of service companies, service management has become of one of the challenging areas in operations management. Several characteristics of services, including high rate of human capital, presence and role of customers in the service creation, the simultaneity of service creation and consumption, and customers' low tolerance for waiting have made behavioral issues an important aspect of managing service companies [90]. In this section, we discuss behavioral issues in service design and waiting line management.

7.1 Operations Management Context

Managing waiting lines is one key area in service management. It has a significant impact on customer satisfaction. Several studies have focused on the behavioral factors that can influence waiting time perception. Perceived waiting time has a significant effect on customer satisfaction [91, 92]. Methods have been suggested to influence perceived waiting time, including the use of entertaining activities, peripheral services, music [93, 94, 96], television programs [97], good smells [98], and journals, menus, and brochures [99]. Different types of visual and auditory distractors can help fill individuals' time and decrease their perception of waiting time [100].

In addition to the studies that have focused on distractors and their effect on perceived waiting time, several studies have focused on the behavioral effects of different queueing systems both on the customers and the servers. Some studies have examined the effects of single-queue compared to multiple-queue systems. In recent years, many companies have changed their queueing system from multiple-queue to single-queue systems, also known as server pooling [101]. Based on queueing theory, server pooling can increase worker productivity, decrease idle time and therefore, reduce customer waiting time [102]. Behavioral studies, however, have shed light on the impacts of this change on the behavior of servers. In one study,

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researchers examined the effects of queue structure (single vs. multiple queue systems) and queue-length visibility (full vs. blocked visibility) on worker productivity. Single queue system and blocked visibility resulted in server slow-down. Task interdependence and feedback saliency were mentioned as the behavioral drivers of these effects. These negative effects can mitigate or eliminate the positive effects of single-queue systems on server productivity and customer waiting time. The design of payment schemes that provide reward for fast performance and are based on the number of customers served by each worker can help mitigate these negative effects [103]. In another study, researchers examined the effect of a shift from a traditional referral system (i.e., multiple queue structure) to a centralized referral system (i.e., single queue structure) in healthcare. The results showed that centralized referral system can result in higher referral rates to specialists among high-confidence general practitioners [104]. This result implies that increase in the referral rate might mitigate or neutralize the positive effect of central queue referral system on patient waiting time.

7.2 Individual Attributes, Heuristics, and Biases

One of the biases that influences behavior in service management is related to the individuals' differential view to the experiencing self and remembering self. Individuals' perception of an event while experiencing it differs from their perception after the event. In one study on patients undergoing colonoscopy, researchers asked patients to report their level of pain on a 1-10 scale every 60 seconds during the process. The level of pain was asked one more time after the process ended. The results of this study showed that the best predictor of perceived pain after the process was the average of the maximum level of pain during the process and the level of pain at the end of the process. In addition, the process duration did not have any effect on the perceived pain even though the process duration changed between 4 and 69 minutes. The results of this study and other related ones [105, 106] highlight the role of three factors on how an experience is remembered: 1) the pattern or the sequence of good and bad events, 2) the high and low points, and 3) the ending point of the experience. People pay attention to the trend of events and prefer experiences that have an improving trend. In service, this means that people prefer services that have a trend of improvement and progress. In addition, service ending is important since people remember the ending points more than other parts of the service after the experience is over [9]. In another study, researchers found that the individual's perception of progress towards their goal during the service process positively influences their choice of service [46].

Other behavioral issues can also influence customer's perception and satisfaction with the service process. Three behavioral elements of emotion, trust, and control are among the most important ones [107]. Regarding emotions, understanding the type of customer emotions and responding to it accordingly can help influence customer feelings in a positive way. Providing consistent services and giving motivated response to errors in the service process can help build trust and loyalty among customers. The feeling of choice and control over the service process is another important factor that can contribute to service satisfaction. People feel more comfortable and happier when they feel some control over the service process. In many cases, the choice can only be a symbolic one, but it can significantly increase customer satisfaction [107, 108]. As one experimental study indicates, blood donors who were allowed to choose the arm for blood drawing felt significantly more comfort compared to those who were not given the choice [109].

7.3 Individual Differences

Individual differences have not been mainly studied in service management. Similar to other areas differences in thinking style can influence people's perception of the service process. Individuals who have an analytical thinking style might have a more accurate estimation of their waiting and service time compared to those who are less analytical. In addition, processing style can influence people's perception of service quality. Individuals who have a global processing might have a more accurate evaluation of the service quality because they consider all aspects of the service process in their evaluation. On the other hand, individuals who have a local information processing might consider more salient aspects of the service in their evaluation of the service.

8. Demand Forecasting

Forecasting is one of the main inputs in decision making in operations and supply chain management. Improvement in forecasting can have a significant effect on increasing decision making quality and decreasing operations management costs [110]. Although many quantitative methods have been developed to improve the quality of forecasting, the decisions are still made based on judgment [111]. Even in cases where quantitative methods are used, individuals' judgment influences the forecasting process and the final decisions [37]. Studies in a large international pharmaceutical firm show that only 50% of the experts used quantitative methods for forecasting [112]. Another study shows that managers intervened and changed the results of quantitative methods in 78% of the companies that actively used

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such methods [113].

8.1 Operations Management Context

Team-based and collaborative forecasting can help mitigate decision making biases and improve the quality of forecasting decisions [114]. In this way, Collaborative Planning Forecasting and Replenishment (CPFR) is one method for increasing the accuracy of forecasting decisions that creates a collaborative decision making platform for suppliers and customers to collaborate on making forecasting decisions on the internet [115]. Studies have also shown that individuals make more accurate forecasting decisions when the forecasted phenomenon had small nonlinearities and the forecasting horizon was short. On the other hand, in cases where the phenomenon had an exponential distribution with large growth rates and forecasting horizons, the level of forecasting error was large [116, 117]. In one study, researchers examined the effect of decision making speed on performance in time series forecasting. The results showed that forecasting error increased when decision speed was either very slow or very fast [37].

8.2 Individual Attributes, Heuristics, and Biases

In behavioral operations, a few studies have focused on individual attributes, heuristics, and biases that influence decision making in forecasting. In one study, researchers examined performance in time series forecasting. The results showed that individuals tend to over-react to forecasting errors in stable conditions and under-react to errors in unstable conditions [79]. In another study, researchers examined forecasting in censored environments, where the existence of a censorship point results in significant misrepresentation of the observed sample. The results show that individuals show what is referred to as censorship bias. They tend to rely on the censored sample and extend its behavior to the underlying population, disregarding the incomplete nature of this population [118]. In addition, since ordering in the newsvendor problem is partly a demand forecasting task, behavioral studies in the newsvendor problem can also be listed in this group.

In psychology and economics, several studies have been conducted on judgmental forecasting and its associated behavioral errors. A series of studies focus on mental heuristics and biases that influence judgmental forecasting [119]. Three mental heuristics, including representativeness bias, availability bias, and anchoring and insufficient adjustment can negatively influence judgmental forecasting [119, 120]. Representativeness bias refers to the prediction of a phenomenon based on its degree of similarity with the parent population and its salient characteristics, instead of using rigorous statistical analysis. This bias causes the decision maker to ignore the effect of prior probabilities, sample size, and regression to the mean when forecasting a phenomenon. Availability heuristic in forecasting results in basing the forecast related to a phenomenon on the ease of retrieving related information from memory. This is influenced by several factors, including familiarity [121], imaginability [121], and vividness [122]. Anchoring and insufficient adjustment heuristic happens when there is a reference point in the form of an initial estimate or a priori forecast. This reference point acts as a mental anchor that individuals start at and then, adjust it upward or downward based on their information and judgement to reach their final estimate. For example, in forecasting demand for the next period (e.g., next week or next month), usually the average demand acts as the mental anchor; demand for future periods is often predicted to be close to the mean and is insufficiently adjusted for the variance in demand. This pattern in forecasting is referred to as the pull-to-center effect which was discussed in the inventory management section [72, 73].

8.3 Individual differences

In one study, researchers examined the role of decision making style on performance in judgmental time-series forecasting [37]. The results indicated that decision makers who were high on rationality as measured by their cognitive reflection score made better forecasting decisions. This effect remained after controlling for their intelligence.

Other potential areas for future research on individual differences in forecasting include information processing and system thinking. Since forecasting decisions require one to look at the phenomenon in the long run, global perspective can help in making more accurate decisions and considering the patterns of changes over the long run. System thinking can also help with considering the dynamics of the events and the environment and incorporating system characteristics in forecasting decisions. This can result in more accurate forecasting decisions.

9. Future Directions

The review of the literature shows that there are gaps in the literature in each of the operations management areas. These gaps provide opportunities for researchers to conduct in-depth empirical studies in each of these areas to increase and expand knowledge in each of them. Each of these areas and their suggestions for future research were discussed in the related section.

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In new product development and project management, a review of the literature shows that most studies in this category have been conducted a long time ago. In fact, most of the behavioral studies categorized in this line are mostly conducted before the emergence of behavioral operations as a separate field in operations management. From the perspective of operations management context, new studies on feedback, goal setting, and decision making are needed to enrich the literature. In the individual characteristics line, new studies are required to examine the effect of different heuristics and biases and to provide ways to mitigate them in this context. Regarding individual differences, analytical thinking and global processing can be studied as the individual differences that can help mitigate the deviations from rationality. Therefore, these individual characteristics can help mitigate heuristics and biases such as sunk cost effect, endowment effect, overprecision bias, and planning fallacy and hyperbolic discounting. As previous studies in this line suggest, system thinking can have a positive effect on project performance through its effect on psychological safety and information sharing among project team members [33].

In quality management and control, there are many potential areas for future research specially in individual characteristics subcategories. Regarding heuristics and biases, previous studies have suggested several biases such as attribution and blame error [9], confirmation bias, law of small numbers, and illusion of control [13]. Future studies are required to empirically test these biases and ways to mitigate them in the quality management context. Regarding individual differences, stock-flow understanding is an individual characteristic that can be beneficial. Quality management and control systems are stock-flow systems in nature. Improvement activities can help increase the stock of capabilities. On the other hand, allocating resources to everyday work will leave no time and resources to increase the stock of quality processes. This will lead to a spiral of declining capabilities, referred to as capability trap in the literature [123, 124]. Stock-flow understanding will safeguard against capability trap by giving the ability to understanding the dynamics of quality management and improvement in the operations management processes [35]. Stock-flow understanding can have a significant effect on performance in other OM areas including production management, inventory management, and forecasting due to their stock-flow nature.

In production management, individual characteristics are mainly understudied and have potential for future research. In inventory management, most of the studies focus on the individual characteristics with few studies on OM context. Thus, characteristics of OM context need further attention in inventory management area. In service management, there is a large body of research on the OM context, including service design, waiting lines and queueing systems. In individual characteristics subcategory, many conceptual studies that highlight the importance of individual factors such as the difference between experiencing self and remembering self and factors such as emotion, trust, and choice. However, empirical studies specially in the form of experimental studies in operations management context are missing to provide support for these propositions. In forecasting, studies need to be conducted in all different subareas to give a better understanding of the nature of behavioral issues in forecasting. While studies in the newsvendor problem partly overlap with forecasting problems, more studies are required to examine and highlight the unique nature of forecasting problems in OM context.

10. Conclusion

Behavioral operations management has become one of the main areas in operations management. What distinguishes this area as a new branch in OM is the emergence of new areas and research methods that allow researchers to examine the role of humans in decision making and performance in operational systems. The multi-disciplinary nature of this field has made it one of the challenging and interesting areas for researchers in OM and other related fields [125]. Some of the main areas in operations management include project management and new product development, production management, inventory and supply chain management, service operations, and forecasting. Behavioral operations management attempts to incorporate the role of humans and their characteristics in operational decisions in order to improve the quality of organizational decision making and performance.

OM models have traditionally had several characteristics that are based on the assumptions of hyper-rationality. Based on these assumptions, individuals: 1) focus on their self-interest and their main purpose is to maximize their personal profits, 2) make decisions in a completely conscious and informed way, 3) have access to all the required knowledge and information and make decision based on them, and 4) try to find the optimal solution when they make decisions [126]. What happens in reality is that individuals do not act based on these assumptions when facing problems in operational systems. In behavioral operations management, such hyper-rationality assumptions are challenged and factors such as emotions and feelings, stress and fatigue, learning, personal relationships and interdependence are considered. Considering these factors can help in better describing OM phenomena and finding

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solutions to their related problems. In real world, individuals do not act based on the assumptions of hyper-rationality. Behavioral operations management first attempt to find the type of behavior that does not match with these assumptions and then, consider these types of behavior in finding solutions to operational problems.

In this paper, we discussed the key areas in behavioral operations management. Apparently, the field currently relies on a few main research areas, including heuristics and biases, bounded rationality, motivational mechanisms, feedback, and learning. There are still many opportunities to expand the literature. A wide range of studies have focused on identifying the type of decision making and behavior that deviate from the rationality assumptions. For example, one line of studies has focused on heuristics and biases that affect decisions in inventory management, ordering, and forecasting.

Furthermore, heuristics have been mainly viewed as cognitive limitation that act as a liability in decision making and behaviour. This is evident from the common use of the term "heuristics-and-biases" in BOM literature [10, 25]. However, as some researchers have argued, heuristics can be beneficial. This approach is demonstrated by the fast-and-frugal program which shows how heuristics can be as asset due to their adaptive nature [3, 127]. Adaptive heuristics result in outcomes that ensure the competitiveness and success of their users [128]. More studies are required to view heuristics from this positive perspective.

Additional studies are required to provide ways to mitigate decision making errors and improve performance in operational settings. There are a few studies on learning and feedback in areas such as inventory management [72, 73, 81]. However, the results are mixed and in some cases, the decision making biases have been robust to these intervention [88].

Regarding individual differences, cognitive abilities and rational decision making style have received most attention [36, 37, 89]. Since the main purpose of BOM research is to stay away from the assumptions of hyper-rationality, other individual characteristics need more attention. Examining the role of decision making styles such as global processing style [129], creative thinking [130], and design thinking [40] on solving operations management problems can be beneficial. These individual differences can help in solving problems in OM contexts such as project management and new product development where creativity and innovation are highly important. Stock-flow understanding is another individual ability that has a high potential for influencing problem solving in OM contexts. Operation management systems are embodiments of stock-flow systems [35]. Future studies are required to examine the effect of stock-flow understanding on performance in different OM contexts.

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