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INTERACTION BETWEEN AUTOMATION AND HUMANS IN SUPPLY CHAIN PLANNING

Larysa Shchekhovska. «Interaction Between Automation and Humans in Supply Chain Planning». *Automation is transforming supply chain planning (SCP) processes, replacing human tasks with technological solutions. While automation offers efficiency gains, the interaction between humans and automated systems presents behavioral challenges. This study investigates how decision-makers in SCP processes learn to correct errors when interacting with automated demand forecasting systems versus human planners.*

Drawing from psychology and behavioral theories, we examine the effects of interaction type (automated system vs. human) on learning, operationalized as performance improvement over time. Further, we analyze whether this relationship is moderated by cognitive psychological traits (positive attitude towards technology, technology anxiety/dependence) and socio-psychological traits (social influence based on subjective norms, social influence based on image) of the human decision-maker.

Our article contributes to supply chain management research by introducing automation-human interaction, providing a temporal learning perspective on performance, and integrating cognitive and socio-psychological moderators. Insights are offered on how to facilitate effective human-automation collaboration by managing socio-psychological influences. Limitations and future research opportunities, including cultural contexts and artificial intelligence, are discussed.

Keywords*:* supply chain planning, automation, human-automation interaction, decision-making, learning, behavioral operations, cognitive psychology, social psychology, technology acceptance, demand forecasting

Лариса Щеховська. «Особливості взаємодії людини і автоматизованих систем під час планування ланцюгів постачання». *Автоматизація трансформує процеси планування ланцюгів постачання (SCP), замінюючи традиційне виконання технологічними рішеннями. Хоча автоматизація забезпечує підвищення ефективності, взаємодія між людьми та автоматизованими системами створює поведінкові проблеми. У цьому дослідженні досліджується, як особи, які приймають рішення в процесах SCP, вчаться виправляти помилки під час взаємодії з автоматизованими системами прогнозування попиту і людини.*

Спираючись на психологію та поведінкові теорії, ми досліджуємо вплив типу взаємодії (автоматизована система проти людини) на навчання, реалізований як покращення продуктивності з часом. Далі ми аналізуємо, чи модерується цей зв'язок когнітивними психологічними рисами (позитивне ставлення до технологій, тривога/залежність від технологій) і *соціально-психологічними рисами (соціальний вплив, заснований на суб'єктивних нормах, соціальний вплив, заснований на іміджі) особи, яка приймає рішення.*

Ця стаття сприяє дослідженню управління ланцюгами постачання, запроваджуючи автоматизовану взаємодію з людиною, надаючи часову перспективу навчання продуктивності та інтегруючи когнітивні та соціально-психологічні модератори. Пропонується уявлення про те, як сприяти ефективній співпраці людини та автоматизації шляхом управління соціально-психологічними впливами. Обговорюються обмеження та майбутні дослідницькі можливості, зокрема, культурні контексти та штучний інтелект.

Ключові слова: планування ланцюга постачання, автоматизація, взаємодія людини та автоматизації, прийняття рішень, навчання, поведінкові операції, когнітивна психологія, соціальна психологія, прийняття технології, прогнозування попиту

Introduction. The ongoing digital transformation with its technological advancements has an immense impact on future supply chains. One element connected to these technological advancements in SCM is automation, the replacement of existing resources, also regarding tasks performed by humans, through technology, which is expected to lead to considerable performance improvements for supply chain planning (SCP) processes.

Nevertheless, automation of processes comes with behavioral challenges in the interaction between automation and humans, especially because automation itself is imperfect and not always reliable. Hence, also innovative automation approaches in SCP, such as automated demand forecasting systems, are not free of editors, and have inherent limitations, especially if not all information is known a priori. In this context it must be noted that SCP processes, which aim at aligning the demand side with the operations capacity, are decomposed and carried out across different departments and human decision-makers.

Therefore, despite all technological advancements, human decision-makers will not become less important as intuition, trust and experience are expected to remain key competences [5]. Yet, it remains unclear how humans correct automated demand forecasts, and Fawcett and Waller ask whether "managers have the emotional fortitude to make and stick to decisions based on the analytics - even if/when they do not fully comprehend why"[7].

Analysis of recent researches and publications. The interaction between automation and humans in supply chain planning has been a topic of significant research and discussion in recent years. As automation technologies continue to advance, their integration into supply chain processes has become increasingly prevalent. However, finding the right balance between automation and human involvement remains a crucial challenge. These authors represent a diverse range of perspectives and research focuses within the broader topic of automation-human interaction in supply chain planning: N. Sanders, R. Basole, M. Bourlakis, M. Gerschberger, Yi. Zhang, H. Lee.

The purpose and objectives of the study. The study aims to provide insights into how automation-human interaction in SCP processes influences learning behavior, and how various psychological factors related to the human decision-maker affect this learning process. The objective is to understand the behavioral implications of introducing automated demand forecasting systems in supply chain planning from a cognitive and socio-psychological perspective.

Basic material and results. The literature does not offer a consensus on how to study SCP process performance. While some studies have focused on quantity-based ordering patterns, or the squared difference between actual and forecasted values, most studies have focused on the financial impact in terms of profit and loss. The latter approach is particularly managerial relevant and will therefore also be used in this study. Additionally, we extend this approach by the perspective of temporal development [4].

Quantifying the temporal development of profit allows for analyzing whether the decision maker improves in his decision-making behavior while experiencing errors in the automated demand forecasts. This cognitive process can be coined as a form of learning, as psychology defines learning as a sustained change in behavior related to experiences. Notably, the central element of learning in this regard is not only the mere change of behavior, but a change of cognitive capacity, related to gaining new insights from experience, which in this case would enable to conduct improved forecast connections. In the case of this study, the change in cognitive capacity stems from double-loop learning, a specific type of learning, that relies on detecting errors and according correction. Similarly, in the context of the automation literature, learning is referred to as integration, which is "a process that occurs as a result of experiencing automation errors or failures". Combining these views, we define learning as the change of profit over time as a result of error detection through the decision maker, which in the context of our research is the production planner.

Turning to the behavioral outcomes, we introduce three different decision strategies (Fig.1) in the context of the initial described newsvendor setting within which the production planner interacts with the demand planner. All three strategies differ in the expected SCP process performance, with the third one being in the center of interest of this study. Before learning occurs, the simplest decision strategy would be to decide based (1) on the newsvendor properties while neglecting any other information such as demand history or supplied forecast. Compared to this strategy, still in the absence of learning, performance can be increased by (2) a strategy that considers both the newsvendor properties and the provided demand forecast [6]. The provided forecast entails both random error components and systematic error components to simulate the imperfect nature of automation. Therefore, an even better solution could be reached by (3) not only incorporating the demand forecast, but critically reflecting the demand forecast against the actually realized demand of the past periods to identify and additionally incorporate (part of) the systematic forecast error in the decision about future production quantities. Ultimately, this learning behavior enables the production planner to adjust the forecast in order to actively increase the SCP process performance.

In a decision task related to production quantities, as the one viewed in this study, from a behavioral perspective, the performance improvements induced through forecast corrections of the production planner depend on two mental processes. First, on incorporating the information provided by the demand planner to make decisions, and second, on critically reflecting the information in order to identify systematic error patterns in the forecast in order to improve decisions over time. As such, the behavior in question in this study is linked to two behavioral aspects: (1) incorporating the demand forecast, and (2) critically reflecting the demand forecast against the actual demand in order to identify systematic forecasting errors [1].

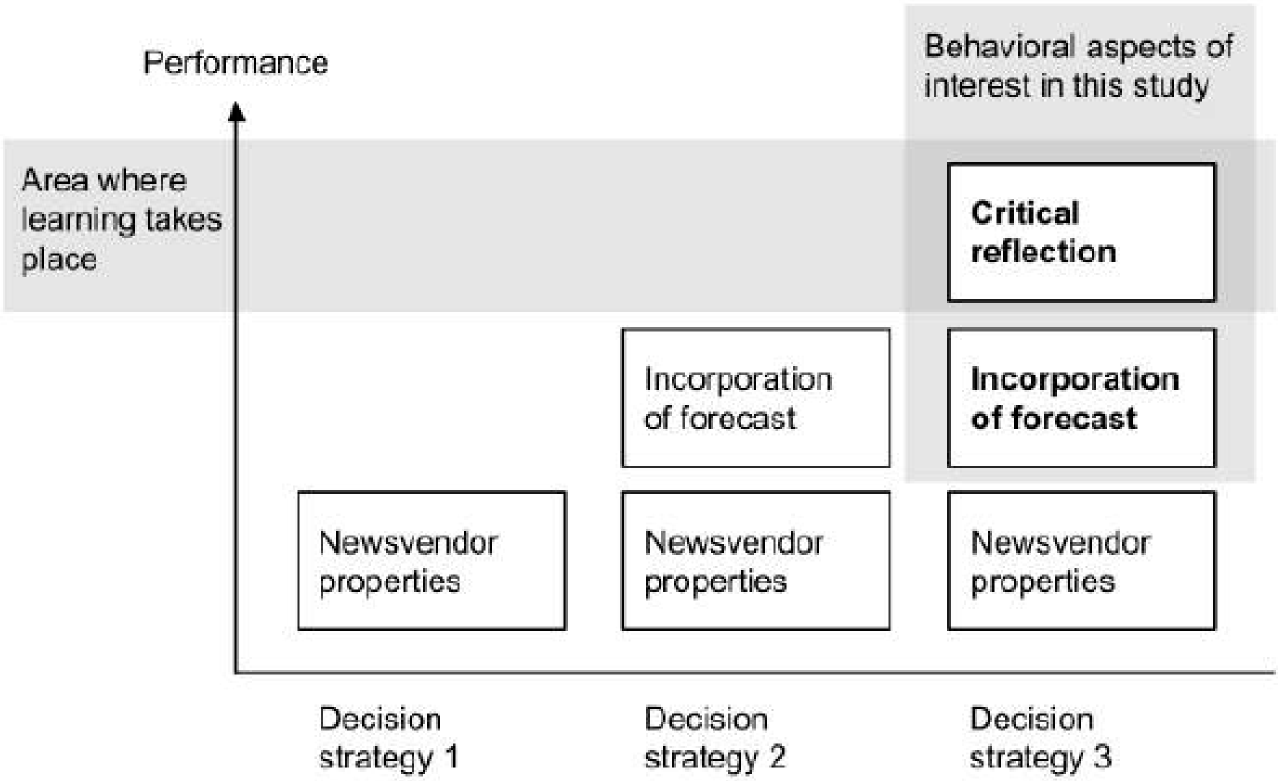

Figure 1 – Decision strategies and behavioral aspects
Source: developed by the authors

The main rationale behind this study is the assumption that a production planner's reaction to demand forecasts will differ depending on whether the forecasts are generated by a human or an automated forecasting system. This effect is thought to be moderated by psychological factors related to the production planner. For instance, an individual who feels pressured by norms to increase usage of new technologies may be less inclined to critically evaluate and fully engage with the automated demand forecasting system's projections. Consequently, when receiving automated demand forecasts, someone experiencing strong social pressure to utilize the automated system would exhibit smaller performance-improving forecast adjustments compared to someone facing little or no such normative pressure. In essence, the perceived source of the forecast (human vs. automated) and the individual's psychological orientation towards technology adoption norms are hypothesized to interact and influence how productively they incorporate the forecasts into planning.

The behavior of the production planner is, according to corresponding theories, the result of different cognitive and socio-psychological factors, where the former relates to factors "within the mind" of the decision-maker and the latter to the relationships of the person to other persons or groups. Moreover, according to the theory of planned behavior and the unified theory of acceptance and use of technology (UTAUT), behavior depends on the behavioral intention to perform the behavior in question, which in tum depends on various factors [2].

Our research will argue that the use and critical reflection of demand forecasts that stem from an automated demand forecasting system, as compared to those stemming from a human demand planner, will depend on different factors related to the production planner's relationship to technology. As such, the concepts derived from the theory of planned behavior and from UTAUT serve as moderators. The former theory, in combination with the technology adoption literature, emphasizes that the attitude towards the behavior and the corresponding personal beliefs are highly relevant within the cognitive psychological domain. Here, Rosen offers a set of comprehensive concepts that reflect the attitude towards technology, of which the two most central and relevant concepts are positive attitude towards technology (PATT) and technology anxiety / dependence (TAD). PATT is defined as a general positive opinion about technology, including "the importance of keeping up with technology trends, the assertion that with technology anything is possible, getting more accomplished with technology, and the belief that technology will provide solutions to many of our problems". PATT has been extensively studied with regard to various technologies from different areas. The area of application of the concept of PATT ranges from electronic communication channels via nuclear power to heart transplants. In contrast to PATT, TAD reflects situations where persons feel dependent on technology so that an anxiety arises of being without technology, such as a smartphone or the internet. In this regard, dependence on technology means that the individual would find it difficult to refrain from its usage [10].

Complementing these two cognitive psychological factors, the second theory, UTAUT, offers an extensive view on socio-psychological factors that impact behavior. From these, we draw on social influence based on subjective norms (SISN) and on social influence based on image (SII). SISN is one of the most central and well-established constructs regarding the use of technology and was already proposed as part of the theory of planned behavior, and has been applied and refined extensively over time. It puts normative expectations of other persons in the focus and is defined as "the person's perception that most people who are important to him think he should or should not perform the behavior in question".

SII, in contrast, puts the self-image into the focus. This concept originally builds on Moore and Benbasat who extended the view on social influence by rooting the social influence not in the norms and expectations of others, but rather in the image that can be built via usage of technology. SII is defined as "the degree to which use of an innovation is perceived to enhance one's image or status in one's social system" [8].

Given the wide range of potential individual behaviors and preferences, it can be concluded that for some production planners, an automated demand forecasting system may be preferable, while for others, a human demand planner may be more favorable. Therefore, we conclude that neither setup is inherently better: The type of interaction (automated demand forecasting system versus human demand planner) does not significantly impact learning outcomes.

In other words, there is no one-size-fits-all solution that is universally superior. The appropriateness of using an automated system versus a human planner depends on the specific behaviors and preferences of the individual production planner. Ultimately, the learning process is not significantly affected by whether the demand forecast comes from an automated system or a human expert.

Positive attitude towards technology is an important driver of successful implementation of new technologies as profound empirical evidence exists for the Linkage between attitude towards technology, employee's intention to use new technology, and eventually the actual usage of these technologies. Additional evidence for the link between behavioral intention and actual behavior can also be found in the theory of planned behavior. That means strong PATT, with people exhibiting a favorable attitude towards the technology in question, leads to technology being used more widely and effectively. Thus, stronger PATT would also lead to a stronger incorporation of the forecast into the decision-making process of the production planner. However, learning over time additionally requires critical reflection of the demand forecasts in order to allow the decision-maker to identify systematic errors in the forecast, regarding how much the forecast deviates and in which direction the forecast deviates. Here, the effect of PATT requires a differentiated discussion. A non-positive attitude may result in outright rejection of the automated demand forecasting system. Evidence for such an effect can be found in previous studies that have outlined the importance of strong PATT for successful acceptance of technology and consequently engagement with the technology. Therefore, with low PATT no engagement with the system may occur, not even a critical one [7].

On the contrary, decision-makers with an absence of positive attitude might be more critical towards the automated demand forecasting system and may therefore also spend more effort in identifying its potential shortcomings.

Decision-makers that exhibit high TAD feel dependent on technology, so that anxiety arises towards being without technology, and, per definition, find it difficult to refrain from using available technology [3]. Here, dependence implies that a decision-maker will incorporate forecasts supplied by an automated system into his decision-making. However, in contrast to the above situation of a strong PATT, high TAD makes persons overly dependent on technology, to a degree where the technology usage can have severe negative implications [4]. The reason for this is an increased level of techno stress in people with high TAD. Techno stress is an established theoretical concept, that has first been introduced by Brod and was since then steadily extended and refined. It comprises "any negative impact on attitudes, thoughts, behaviors, or body psychology caused directly or indirectly by technology" [6]. Highly relevant to this study is the observation by Wang who note that techno stress in individuals, for example provoked through technology dependence, may inhibit further learning. With this concept in mind, we argue that high TAD and the resulting techno stress are contrary to freedom of mind and critical thinking, which is why the production planner will follow the automated demand forecast more closely, leading to a stronger incorporation of the forecast into the decision, with the final decision value of the production planner being closer to the suggested forecast as compared to people with lower TAD. This also implies an under-reliance on one's own capabilities and over-reliance on technology, reducing the ability to use one's own judgement required to identify error patterns in the automated demand forecasts. Following the above lines of argumentation, decision-makers with high TAD, because of their psychological dependence, find it difficult to refrain from its usage. They are characterized by a compulsive use of technology that hampers critical reflection of the automated demand forecasting system and the forecasts it supplies. Therefore, decision-makers faced with an automated demand forecasting system will learn the less, the stronger their TAD is [5].

A decision-maker who experiences strong social influence based on subjective norms (SISN) to use new technology will, according to UTAUT have a stronger intention to actually use this technology. Venkatesh argues that in a mandatory setting, where only the new technology is available for use and no other alternative, social influence as a socio¬psychological factor has a positive effect on the decision-maker's intention to use the technology. Therefore, high SISN leads to a stronger incorporation of the forecast into the decision-making process of the production planner. The underlying mechanism is a compliance effect, which is particularly pronounced in the early phase of technology usage before usage is habituated. However, according to the theory of planned behavior, norms can be understood as a "social pressure to perform or not to perform" a certain behavior. This is consistent with the argumentation that SISN leads to compliance, and complying is fundamentally different from the critical reflection necessary to identify error patterns in the forecast. One source provides substantial evidence by arguing that people might deviate from norms and act contradictory over time, which aligns with a certain theory that states the effect of "normative pressure will diminish as time passes." Additionally, according to another perspective, purely extrinsic stimuli and motivation imposed through normative expectations have a "negative effect on complex, mentally-engaging tasks, such as critical thinking". Consequently, strong social-institutional subject norms (SISN) hinder critical reflection and learning when a decision-maker is confronted with an automated demand forecasting system. In essence, the evidence suggests that over time, people may break from normative pressures. Moreover, externally imposed norms can negatively impact complex cognitive tasks like critical analysis. Therefore, strong institutional norms demanding technology usage can impair a decision-maker's ability to critically evaluate and learn from an automated forecasting system.

For SII and its effect on the usage of technology, we also draw on UTAUT but then extend this view by further arguments regarding its effect on learning. With regard to learning, SII differs from SISN as there is no social pressure present that stems from normative expectations. Instead, the social influence in this case is due to the prospect of improving one's own image when using new technology. According to UTAUT, the effect of SII is analogues to SISN regarding the mere usage of technology, but we argue that SII differs in its effect on the way technology is actually used. The reason for this is the absence of impeding factors hampering the cognitive process of critical reflection, while instead a more appealing motivation is evoked through SII. Seeing the prospect of enhancing one's own image as a much more positive stimulus with a desirable outcome lets us argue that a decision-maker with strong SII is much more motivated intrinsically. Here, Rogers states that "one motivation for many individuals to adopt an innovation is the desire to gain social status" [10]. Furthermore, recent research provides evidence for reciprocal behavior driven by positive feedback. Studies have shown that positive recognition has a favorable impact on people's willingness to put in effort, as well as their attitudes. Therefore, it is argued that the positive recognition effect likely acts as a strong motivator not only to use a technology but also to engage in related mentally-challenging tasks. In this case, to critically evaluate the system's forecast in order to leverage opportunities for enhancing one's image beyond merely using the technology, through improved usage performance. Consequently, individuals with a higher degree of self-image motivation and a resulting higher drive to engage in image-building tasks are more likely to exhibit learning behavior. In essence, positive feedback and recognition can motivate people to put in more cognitive effort, not just use a technology superficially. The desire to build a positive self-image acts as an incentive to critically analyze automated forecasts and learn how to utilize the technology more effectively, not just passively use it. Those highly motivated by self-image considerations tend to demonstrate more active learning behaviors.

Conclusions. As outlined, research on automation-human interaction in SCM is scarce, particularly from the behavioral research perspective. This is remarkable as automation and its interface with human actors plays an important role in many other areas of life such as "aircraft and air traffic control, nuclear power, manufacturing plants, military systems, homes, and hospitals" [1]. Given this importance, we argue that also SCM needs to quickly catch up and advance in the understanding of automation-human interaction while integrating the behavioral perspective. This is particularly relevant as it is argued that human interaction will still be in necessary in the future, even if we advance to more sophisticated technologies such as artificial intelligence applications. By studying the impact of automation-human interaction on learning in supply chain planning (SCP) processes, and by discussing related theoretical concepts and developing and applying an experimental research design, this study contributes on both the theoretical and the managerial level.

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