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A Framework for Understanding Human Factors Issues in Border Control Automation

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Abstract. New security threats and increasing traveler flows as well as needs to enhance facilitation and security in EU external cross-border traffic have accelerated the use of novel technologies in border control. Especially at airports, automated border control, more commonly known as e-gates, have been taken widely into use. With e-gates, travelers perform border check as self-service, and the role of the border guards is to monitor or possibly also assist travelers passing the border. The introduction of automated systems significantly reshapes current ways of conducting border control from the border guard's perspective, and automation thus requires new skills from them. Understanding the effects of automation on the work tasks and work performance of border guards requires thorough examination. This paper introduces key Human Factors issues affecting border guard and border control system performance. The results are based on literature review and field studies conducted in different border control points within six European countries. The paper presents a Human Factors framework for understanding the complex nature of the border control and different factors influencing to both border control process and border guard performance within it.

Keywords: EU, Schengen area, automated border control, border digitalization, human factors, human factors framework

1 Introduction

To improve the effectiveness of EU border control in the context of growing passenger flows, cross border threats and budget restrictions, new socio-technical models are being envisioned with high reliance on automatic technical systems, such as e-gates. During the last years, especially largest airports in EU member states have introduced automated border control (ABC) for border checks. In 2017, ABC systems were extensively used at airports in 16 EU member states, and they are expanding to other type of borders as well [1]. Implementations in airport terminals research has been made to enlarge the systems to other border types, including road, sea and rail [2]. This technological change has been driven on the one hand continuously increasing passenger flows [3] and demands on performing border checks effectively, efficiently and with high security as well as serving travelers better by seamless travel and trade experiences

[4]. European border and coast guard agency, Frontex, defines the main objective of automating the border control to reconcile traveler facilitation and security [5].

Border control environment is a complex and demanding environment to automate and develop solutions, as all systems must fulfil the challenging and somewhat contrary aims. As a precondition all systems must be effective in enforcing the law related to the border control, they should be as unobtrusive to the flow of travelers and goods as possible, additionally they should respect the rights of an individual and finally they should be cost-effective with regard to the use of both public and private resources [2].

The Schengen Borders Code [6] sets the framework for the various border control measures, which are implemented at the external border control points (BCPs) of the Schengen area. This regulation provides the framework under which the automated, self-service border control concepts operate. Smart Borders Package and the establishment of the EU Entry-Exit System represent the next significant evolution in border control [7]. The proposed changes include additional biometrics verification, replacement of manual stamping of passports by automation and the possibility for third country national, TCN citizens to use automated, self-service border checks systems. Thus, it is expected that the use of automated systems, such as ABC-gates with document and biometrics scanners will increase in border control.

Automated border control (ABC) is an automated system, which performs the same tasks as in the manual border control with a high degree of automation [5]:

- 1) checks that the traveler trying to cross the border is carrying a genuine and valid travel document,
- 2) verifies biometrically that this travel document belongs to the traveler trying to cross the border,
- 3) checks that the traveler is eligible for the system and entitled/authorized to cross the border,
- 4) allows/denies passage according to a predefined logic, sometimes requiring the intervention of the border guard operating the system
- 5) guarantees the security in the overall process, meaning that only a traveler who has been cleared is allowed to cross the border and that travelers who have been rejected are properly handled

A border guard supervises the system and controls multiple self-service gates. The work shifts from checking travelers individually to monitoring a system outcome and exceptions indicated by the system or acting upon border guard's assessment. Table 1 describes the roles and tasks of border guards in manual process and in automated border control process [5, 6]. Border guard's tasks in the automated process are divided depending on the guard's role, whether the guard is monitoring or assisting traveler on using automates. The highlighted cells presents those manual tasks that automated border control is set to replace.

Table 1. Border guard roles and tasks in manual and automated border control process

FIRST LINE BORDER CHECKS		
Manual process	ABC process	
<i>First line border guard</i>	<i>Operator</i>	<i>Assisting personnel</i>
verify presented travel document(s) and other required documents verify traveler identity	monitor the user interface of the application and react upon any notifications given by it	handle exceptions and assist operator
verify conditions governing entry verify documents authorizing residence and pursuit of professional activity	manage exceptions and makes decisions about them	conduct brief interviews and redirect travelers to second line check if found necessary escort travelers to second line checks when needed
consult relevant databases providing information for example on stolen, misappropriated, lost or invalid documents	communicate with the assisting personnel for the handling of exceptions at the e-Gates	monitor and profile travelers queuing in the ABC line and using the e-Gate
monitor and profile travelers queuing to the control desk	monitor and profile travelers queuing in the ABC line and use e-Gates to look for suspicious behavior in travelers	conduct first line border checks in case of ABC system failure
communicate with second-line checks if needed	communicate with second-line checks if needed	provide on-the-spot assistance to travelers

The automation of work will have consequences on human performance [8], and implementing new technology is likely to cause reactions among employees. This is mainly because new systems alter the ways in which employees perform their work. In addition, related work processes and tasks as well as the working environment are likely to change. Furthermore, employees may be unsure of the overall impacts that automation will have on their work. Automation can have both positive and negative effects on human performance. The latter effect may arise, because introducing automation changes the type and extent of feedback that operators receive, as well as the nature and structure of tasks people perform [9]. Attitudes that are shaped by the reliability or accuracy of the automation will influence an employee's willingness to use automation [10]. Moreover, the probability of potential use of automation is influenced by various factors, such as trust in automation, self-confidence in manual performance, perceived risk, and fatigue [11]. In addition to performance, automation may have effects on human factors like situation awareness, workload, motivation, stress and trust [12, 13].

Multiple studies present models, which investigate human factors in different contexts where technology is used to assist employees in their work tasks [e.g. 13, 14, 15]. Some human factors models have also been standardized by standardization organizations [16]. However, these models are quite narrow leaving many important aspects uncovered. This paper introduces a Border Control Human Factors Framework

(BCHFF) to understand the complex and dynamic nature of border control environment, where multiple factors influence the employee and the system performance. The development of the framework is based on literature review and field studies in six EU countries. The created framework aims at forming a comprehensive model to visualize underlying human factors in border control and interrelations between them. The framework helps to understand the border control context and how work performance is influenced by automation. The objective is to facilitate the development of systems that are both efficient and user-friendly to operate.

2 Human factors in front of border digitalisation

Human factors and ergonomics (HFE) focuses on systems in which humans interact with their environment [17]. The ISO 6385 standard [18] as well as the International Ergonomics Association [19] defines that ergonomics addresses the interactions between the humans and other components of a system, such as other humans, machines, products, services, environments and tools, as appropriate. The Health and Safety Executive, HSE [20] defines human factors as "referring to environmental, organizational and job factors, and human and individual characteristics, which influence behavior at work in a way that can affect health and safety". Thus, human factors is concerned with 1) what people are being asked to do (the task and its characteristics), 2) who is doing it (the individual and their competence) and 3) where they are working (the organization and its attributes). In addition, the wider societal context has an influence on all these three areas.

The ISO 26800 standard provides an integrated ergonomic framework and defines a human-machine system model, which deals with the interactions in the system between the human and other parts [16]. In the model, the human and the machine are integral parts of the system, and they exist within a spatial environment, which in turn exists within a physical and an organizational environments. In addition, the social, legal and cultural environments influence the functioning of the system. Kraemer et al. [14] present a macro ergonomic conceptual framework for human and organizational factors in dynamic security system environment that highlight the "social dimension" effects on the system performance. The framework categorizes human and organizational factors into five categories: organization, operational environment, individual or operator, tasks and workload, and tools and technologies. The framework contends that a high performing decision support system design and implementation needs a strong notion of both, the social and technical components. Situation awareness, workload, boredom and monotony, motivation and stress, and trust will be the key human factors issues for the future monitoring work, like the air traffic control [13]. Especially issues of stress, trust, and boredom will become more significant because the automation will change the role of the controller from active, "hands-on" controller to relatively passive monitor.

HFE aims to optimize the performance of both the human and physical components of the system. The focus is to improve performance and well-being through system design and by enhancing the integration of humans into the system. Disregarding HFE

in system design may result in sub-optimal end-products with quality and efficiency defects, not forgetting adverse effects on employee well-being and health [17].

The introduction of automated systems will change the work of border guards, and automation thus requires new skills from employees. Usability of the used technology, operational environment and border guard's personal profile are important factors that influence to the work performance [15]. In addition interaction with travelers transforms primarily into supervision of travelers using the e-gates. Nevertheless, the need for human oversight will not disappear, and in the future, border guards are expected to operate more like customs officers – performing risk-assessment and spotting of anomalies rather than frontline passport-checkers [21]. Border guards appreciate the technical tools like document and fingerprint readers because they make them feel more confident about deciding the travelers' eligibility to cross the border [22]. However, even though the technology is considered useful, border guards want to keep the control in their own hands [22].

3 Creating a Border Control Human Factors framework (BCHFF)

3.1 Methods

To understand the complex nature of the border control context, it is vital to study the context from a comprehensive viewpoint: organization, work environment and work tasks as well as used technologies and tools. Understanding human factors of border guards' work involves gathering information about their tasks and their competences. The research and development work was based on real work analysis and co-creation with relevant stakeholders. Thus, the data was gathered both by literature review and by field research.

The field research was performed in border locations that had different experiences and perspectives to automated border control. These studies included interviews with different actors involved in the border control and observations of border guards' performing their daily operations related to border check process. The focus of the semi-structured interviews was to gather human factors information of border control work. Therefore the interviews included themes of organization, BG's activities and tasks, performance, training, soft skills, technology use, evolution of the work and ethical issues. The interviews were fulfilled with observations always when it was possible in the real work conditions.

The field studies were conducted at six European countries and at different border control points: sea, air and rail. Altogether, the study was completed in 19 locations and four border types and over 110 border authority or stakeholder interviews and border guard observations were conducted. All locations implement automated border control solutions functioning alongside with manual border control process and all border guards worked on both manual and automated lines. The amount of the e-Gates, ABC processes and topologies as well as exception handling varied somewhat in different

border control points. In addition, amount of travelers and traveler profile differ in each border control point.

3.2 Data analysis

The studies have indicated that in real settings the work is rarely performed as theoretically planned [23]. In real conditions, the employee has to adapt to the external constraints like technological and environmental challenges as well as internal factors like workload and motivation that may affect to the work performance. The data analysis was grounded on analyzing the real work of border guards aiming to prescribe the tasks border guards actually conduct during the border control. In addition, the organizational and technological issues were analyzed.

The literature review focused on the border related technologies and how they will affect the border guards' work and their operational environment from the perspective of human factors. Based on the literature review preliminary human factors issues that are influenced by the new technology and automation of border control were recognized. This knowledge was used while planning the field studies, observations and interviews with different stakeholders.

All the data gathered from the field studies were integrated in an Excel sheet. The data was grouped into the categories accordingly to the themes used in interviews for further content analysis (e.g. ABC-system, technology, training, working environment, interaction with travelers, ethics and legislation). The qualitative data analysis was performed by profile and categories. Based on the field studies the challenges that border guards have while performing their work tasks were recognized. The factors behind the challenges and their influence to work performance were identified as well as border guards' means to cope with identified challenges. In addition, the aim was to find what kind of good practices can be discovered and how these can be used in other border control contexts as well. Location-specific information is withdrawn from the analysis in order to respect the research permissions made with border organizations.

The gathered data was the starting point for the first model created to define the performance of the border control. This model highlights that the efficacy of performance of border checks with automated system takes into account three main dimensions: speed, security and fairness [24]. This means that the border control has a good performance if the border check is 1) fast, 2) above a good security threshold and 3) with an optimal fairness.

The focus of the speed-security-fairness model was mainly on performance of the border control. Apart from the border control performance, there is performance of single border guard, which is affected by different external and internal factors. The speed-security-fairness model was extended with the main human factors issues that affect to the BG's work performance. These were recognized based on the field studies and literature review. In addition, the environmental factors/layers that contribute to the performance were identified. The border control human factors framework (BCHFF) that combines the models of a general system to the single border guard was created. Performance criteria was also updated accordingly to emphasize the effect of human factors in the overall.

4 HF framework to model interaction between border guards and automated border check

The border control human factors framework (presented in figure 1) aims to combine and categorize different factors to form a general and comprehensive model to visualize the most important factors affecting to border guards' work performance and interrelations of them. The framework is an expanded description of the human-machine-environment system model presented in ISO 26800 [16] and frameworks created for monitoring work [13, 14].

The framework describes different background variables, the environmental layers and functional actors, which together form the overall environment where border guards operate and where the border check takes place. All these factors contribute to the system performance and to border guards' ability to perform their work efficiently as well as general well-being of employees. In addition, these factors affect travelers profile, flow and behavior.

The main human factors issues of border guard, which were identified based on the field studies are motivation, workload, trust, situation awareness and skills. These issues may have impairing or strengthening effects on **border guard's performance**. Border guard's performance deals with the quality and quantity of human errors, quality of decision-making process and quality of customer service (customer feedback). In order to support good border guard performance, it is important to prevent or minimize issues that have impairing effects on border guard's human factors and facilitate the positive ones.

System performance is an outcome of all the factors and interplay and balance between them. In addition, the border guard's performance influences greatly to the system, in this case border control, performance. Overall border control performance can be evaluated through facilitation, security, cost-effectiveness and fairness of the process as well as general well-being of employees.

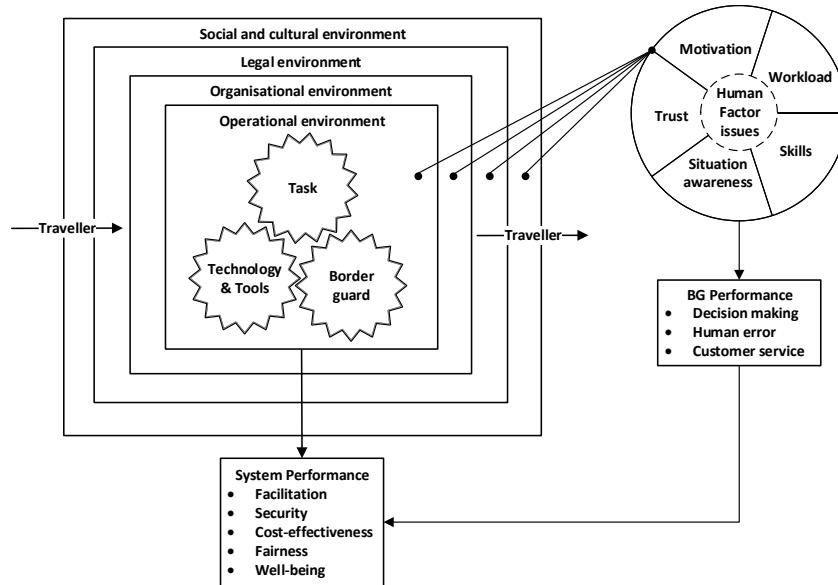


Fig. 1. Border control human factors framework (BCHFF)

Social and cultural environment describes the people, their attitudes, knowledge explosion and public opinion. The cultural environment deals with values, beliefs, norms and accepted behavioral patterns. Social and cultural environments differs from one country to another and it is important to understand how it will affect to border control and border guards' work as well as impacts on travelers' ability, decisions and willingness of using self-service systems. This environment is permanent in nature and the border organization must adapt to it. **Legal environment**, border control legislation and national regulation influences and guides border organizations. The Schengen border code and national laws regulate the border processes in Schengen area. In general, the border checks follow the same procedures across the different member states and in border checkpoints and border types. The legal environment can change but usually changes take time. Legislation defines the border control process and what elements of it can be automated. For instance, in Schengen area current regulation does not allow processing all traveler types automatically, but some tasks needs to perform by human. **Organizational environment** includes organizational culture and structure, and management. It is affected by social and cultural factors and depends on national regulations and rules, but these are applied to the practice by organization. Border control is organized in different ways within the member states of the Schengen area. Usually it is managed by one administrative organization. Most of border control authorities in Europe are police organizations but in a few countries border control is managed by a military organization. In addition, border control processes and topologies as well as shift planning have some variations in different border control points. **Operational environment** includes both physical (e.g. border crossing point) and spatial (e.g. work

station) environments. At each border types there are some characteristics that must be taken into account when considering the human factors of border guard work. The characteristics are related to conditions at the border, other stakeholders involved, environmental conditions, surrounding technology, fixed or moving construction, means of transportation when crossing the border, traveler flows and travelers profile in general. In addition, the implementation and configuration of border control point have an impact on the border control process.

The border check process consists of the three core functional components: **border guard**, **tasks** and (technical) **tools**. In automated border control, the technology has more visible role, but there is always a border guard monitoring the process. The cog-wheels illustrates the close interaction of all these three core components and the importance of their compatibility.

Tasks refer to the border guards' tasks and activities at first line border check. Tasks can include different tasks depending on the type of the border and defined process on the border control point as well as BG's role (performing manual control, monitoring traveler, assisting traveler).

Technology and tools means all the technological tools and devices that border guards have at their use while performing border check. This includes technology used at manual check as well as automated border control technology: e-gates, pre-enrolment kiosks and monitoring and surveillance equipment. In addition, other non-technical equipment such as magnifying glass can be included in this category.

Border guard's individual characteristics and features (physical characteristics, perceptions, personality, behavior, skills, motives, and needs) have significant role to the work performance. Personal features lay the foundation for all activities and performance, these features defines how person acts in certain situation, how one interacts with travelers and is able to cope with challenging situation and stressors. In addition, travelers' behavior and experiences of border control and technology influence greatly to border guard's work.

Human Factors Issues are the factors that have impact on border guards' performance and are shaped as an outcome of all background and environmental variables together. The influence of these issues on performance can be positive, neutral or negative depending on the situation. The key human factors issues identified to influence the border guards work performance are motivation, workload, trust, situation awareness and skills.

Motivation describes why individual acts or does something. Motivation in work is defined as the set of internal and external forces that initiate work-related behavior, and determine its form, direction, intensity and duration [25]. The values such as job satisfaction, professional development and nature of the work were mentioned as factors that inspire and motivate BGs in their work [26]. While considering the increased automation in BG's work it should be reflected that the BGs still desire the opportunity to feel themselves competent while performing monitoring tasks.

Workload consists of both external and internal loads. External load (also work stress) can be understood as an external conditions and demands, which influence on a person's physical and/or mental internal load. Internal load (or work strain) is an individual response to the external load. Individual characteristics and personal features

influence how the effects are experienced and how the one is able to cope with them. Mismatch between demands and capabilities cause suboptimal workload, which can mean either over-load or underload. Unbalanced mental workload may cause monotony, reduced vigilance, fatigue and satiation, which often result in increased number of errors, pro-longed processing time, diverted attention and reduced alertness [27]. In the future, the amount of technology and tools as well as automation will increase in border control work and it will increase BG's monitoring work. Automation can decrease BG's workload in some task as well as increase it in other tasks.

Trust is a new human factor introduced by automation which importance increases when more and more tasks are shifted to automated systems [13]. Trust on technology is seen one of the most important factor in acceptance and adoption of automation [28]. In the framework trust refers to trust on technology, organization and colleagues. Balance in trust is crucial for human-automation reliance; both over-reliance and mistrust are harmful and may lead to misuse and disuse of automation [29]. Overreliance refers to the situation where operator trusts too much on the system, which as a consequence may limit the detection of warnings and lead to misunderstanding of the system functionalities. Mistrust may lead the situations where warning signals of the system are ignored or underestimated. The balance between overreliance and mistrust of technology in BG's work is essential in case of border control automation; the border guard has to be able to rely to decisions made by the technology but they still want to have the control by themselves [22].

Situation awareness refers to the perception of elements in an environment, within a volume of space and time, and comprehension of their meaning and projection of their status in the near future and to integrate this knowledge onto person's current activities [30]. Numerous factors may affect a person's ability to fully comprehend and suitably respond to the challenges posed by the environment in which he/she is operating. The level of automation will affect to the situation awareness and especially the automation of decision-making functions has been found out to reduce operator's situation awareness on the system and work environment. Automation may enhance situational awareness in two main ways: first, by easing the user's workload and, secondly, by assisting the user with the collection and processing the information [31, 28]. On the other hand, the interaction with software tools, electronic displays and database systems may create problems for the work of border guards. Difficulties may arise, for example, from border guards having to deal with unprecedented amounts of information coming from multiple sources as well as from their need to make decisions with help of the technology.

Skills refer to border guard's personal abilities and skills as well professional knowledge gained through experience and training provided by the organization. Both soft and technical skills should be considered. Good versatile skills support performance and smooth communication with travelers, poor or lack of skills instead may in turn have adverse effects on performance (e.g. language skills, social skill, ability to use technology efficiently etc.) Job satisfaction is also linked to the adequacy of the skills/expertise of the operators to their jobs. Introduction of new technology and automatic systems for border control will change the nature of BG's basic skills. It may also introduce new kind of skills and knowledge needs.

5 Discussion

The presented border control human factors framework is intended to be used in identifying the challenges and opportunities resulting from the automation of the border control process. After these are identified, the recommendations and requirements to enhance the system and employee performance as well as finding the optimal task-allocation between human and technology in work automation could be conducted. The important question is that by knowing the human factors issues that affects to BG's work performance how to support border guard's work and decrease the possible disadvantages of the automation such that the balance between efficiency and well-being remains.

Automated border control systems have transformed the role of border guards from active controllers to ones monitoring the system. According to filed studies, the evolution of job and new work tasks increases the border guards' motivation. However, border guards' still desire the opportunity to feel themselves competent while performing monitoring tasks. Involvement in decision-making, problem solving, social nature of work, meaningfulness of own role and societal responsibility were mentioned as important factors for motivation and job satisfaction.

Border check process is demanding task and requires continuous vigilance from border guard. Decrement in vigilance over time is recognized by studies that concluded that people are only able to maintain an initial level of vigilance for a short period before it slowly decreases [32, 33]. In addition to the workload, the boredom is closely related to vigilance, attention management, and task performance [34]. Workload influences to the vigilance and according to the field studies the workload and strain in border check varies a lot due to e.g. border type, time of the year and amount of travelers crossing the border. Organization can support border guards in maintaining their vigilance by reducing the workload and boredom by planning the work shifts to ensure adequate time in monitoring as well as amount of breaks and diversifying the tasks that border guards perform in a shift.

Trust on technology is seen one of the most important factors in technology acceptance and adoption [28]. Automation should be designed to be both technically competent and matched to the task and easily understood and transparent in its operation [35]. Border guards seem to have high trust on automated border control technology since the technology provides them support in the most challenging tasks [22]. However, the field studies revealed that the border guards think that they have important role in border checks since they are more capable of performing some tasks than technology.

Employee satisfaction and engagement contribute to employee's performance [36]. Job satisfaction and engagement have also great influence into turnover rate. According to field studies, the organization and management play an important role in border guard engagement. Regular training seems to contribute positively to job satisfaction through the possibility to enhance personal expertise as well as in maintaining the skills needed to perform the work. This is also pointed out by Frontex, which recommend that initial and follow-up training will be required so that officers can operate the system successfully and contribute to its enhancements [5]. In addition, participants in field

studies highlighted that it is important to understand the meaning of border guard's work and societal role as a whole. They assumed that by understanding the work in a bigger context it might be easier to perform different kind of tasks associated to border guards. In order to maintain the motivation of border guards, it is important that they are able to use their skills while performing their work as well as maintaining their competence.

Usability of technology as well as border guards' experience of using the technology plays an important role in automation. To enhance efficient performance of border control the technology has to provide border guards a suitable, efficient and easy to use tool to perform their monitoring and controlling work [15]. Thus, it is essential not to forget interaction design of humans and automated systems focusing on engaging user experiences in work environment [37]. In the field studies, it was generally argued that automation has lightened and eased BG's work. The automation performs tasks that are often considered challenging and can especially lighten the workload during peak hours.

6 Conclusion

Due to the demands on performing border control effectively, efficiently and with high security the amount of automation and technology for border checks is increasing. The introduction of automated systems significantly reshapes current ways of conducting border checks from the border guard's perspective, and automation thus requires new skills from them. Understanding the effects of automation on the work tasks and work performance of border guards requires thorough examination.

This paper has examined those key human factors issues that automation of border control will have and that influence on border control and border guard performance. By gathering information and experiences from the border control stakeholders from different countries and border crossing points, we have gained a deep understanding of the complex nature of the border control environment. Based on this data we have identified key human factors issues that affect to border control as well as border guard performance. The purpose of this paper is to provide greater understanding of the complexity of the border control context and to identify those human factors that can be used to guide technology development in order to provide such solutions for border control that will enhance both system and employee performance.

The paper presents the human factors framework for border control. The framework combines and describes the different background and functional factors that together form the overall environment where border guards operate and where the border check takes place. All these factors contribute to the system performance and to border guards' ability to perform their work efficiently as well as to general well-being of employees.

The next steps with the framework are validation and formulating the understanding how the framework will support in creating the recommendation for automation of border control.

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