The Impacts of Different Work Locations and Levels of Automation on Crane Operators' Experiences: A Study in a Container Terminal in Indonesia

TAUFIK AKBAR SITOMPUL, Norwegian University of Science & Technology (NTNU), Norway

Due to the increasing demand of higher productivity and safety in the shipping industry, container terminals are increasingly shifting from manually operated container cranes to remotely operated container cranes with semi-autonomous control. The shift from on-site crane operation to remote crane operation does not only affect how well crane operators could perform their work, but also how they experience their work. Eight crane operators, who worked with both manual container cranes and remote container cranes with semi-autonomous control, were interviewed to explore what kinds of experiences that they have as the results of operating container cranes with both operational modes. The results suggest that the location of the operators and the level of automation of the cranes positively and negatively affected the operators' experiences.

CCS Concepts: • **Human-centered computing** → **User studies**.

Additional Key Words and Phrases: crane, remote operation, human-automation interaction, user experience, work automation

ACM Reference Format:
Taufik Akbar Sitompul. 2022. The Impacts of Different Work Locations and Levels of Automation on Crane Operators' Experiences: A Study in a Container Terminal in Indonesia. In *OzCHI '18, November 29–December 02, 2022, Canberra, Australia.* ACM, New York, NY, USA, 9 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

Container cranes play an important role in the shipping industry, as they are needed for loading and unloading containers to and from a ship, as well as moving containers in the storage yard. While it is still common to find container cranes that are manually controlled by operators who work from the crane's cabin, there is an increasing number of container terminals that decided to adopt containers cranes that could be operated remotely and could also work semi-autonomously [8]. The transition from on-site crane operation to remote crane operation with semi-autonomous control at container terminals is mainly driven by the increasing demand of higher productivity and safety, since one operator could control any cranes that exist in the container terminal and operators are also not exposed to accidents that may happen around their cranes [7].

The transition from on-site operation to remote operation with semi-autonomous control does not only affect how well crane operators could perform their work, but also how they experience their work [2]. In safety-critical domains, it is relevant to investigate how the new tool influences user experience, as the presence of negative experience could indicate to what extent the new tool is adequate for the task to be performed [11]. Any inadequacy should then be addressed accordingly in order to prevent accidents from happening. Accidents in container terminals could not only harm workers' lives and properties being shipped, but could also damage the surrounding environment [10].

The objective of this paper is to explore what kinds of experiences that crane operators have as the results of operating manual container cranes and remote container cranes with semi-autonomous control. The definition of experience used

Manuscript submitted to ACM

in this study is the same as the definition of user experience from ISO 9241-210 [6], which is "a person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". Eight crane operators, who worked with both operational modes, were interviewed. The results from this study are the list of positive and negative experiences that the crane operators had as the results of working with both operational modes.

2 RELATED WORK

The main body of literature that investigated the impact of remote crane operation or crane automation on operators' experience is still limited to the first interaction with remote crane operation and crane automation, such as during usability studies (see Sitompul [13] for a review). In addition, such studies were usually conducted in virtual environments or physically controlled environments due to safety concerns. Nevertheless, there are four studies that investigated the impacts of remote crane operation or crane automation on operators' tasks or experiences in real work conditions, and they are briefly described in the subsequent paragraphs.

In the context of tower cranes, Shapira and Elbaz [12] interviewed two crane operators who worked with both manual and remote tower cranes to discover advantages and disadvantages of both operational modes in terms of operators' safety and work conditions. Note that the remote tower crane in this study was still manually controlled by an operator using a portable remote control and the operator was still required to be physically present near the crane.

In the context of container cranes, Karvonen et al. [7] interviewed two groups of operators at two different container terminals. The first group consisted of six operators who worked with manual container cranes, while the second group consisted of six operators who worked with remote container cranes with semi-autonomous control. However, their study focused on how the transition from manual operation to remote operation with semi-autonomous control changed the tasks that the operators have to perform. Note that the remote container cranes in this study were operated by operators who worked from a remote control room.

Still in the context of container cranes, both Abdullah and Handroos [1] and Abdullah et al. [2] interviewed a total of thirteen crane operators, who worked with remote container cranes with semi-autonomous control, from two container terminals. The remote container cranes in both studies were also operated by operators who worked from a remote control room. The study of Abdullah and Handroos [1] specifically investigated the user experience of joysticks at the remote control room, while the study of Abdullah et al. [2] explored positive and negative experiences as the results of operating remote container cranes with semi-autonomous control.

3 THE STUDY

The study was carried out in one of international container terminals in Indonesia, which started its operation in 2019 and had an output of roughly one million twenty-foot equivalent units (TEUs) per year. This container terminal was equipped with four ship-to-shore (STS) cranes (see Figure 1a) and twelve automated rubber-tired gantry (ARTG) cranes (see Figure 1c). Both types of cranes were used for handling containers, but at different locations. The STS cranes were stationed in the quay and they were used for loading and unloading containers to and from container ships. The ARTG cranes were stationed in the storage yard and they were used for loading and unloading containers to and from transport vehicles, as well as for stacking and retrieving containers in and from the storage yard.

The cranes used in the container terminal also had different operational modes. The STS cranes were controlled manually by operators, who where present inside the cabin (see Figure 1b), while the ARTG cranes were operated remotely by operators, who worked from a remote control room (see Figure 1d). The ARTG cranes could also work semi-autonomously, as the cranes could stack and retrieve containers in and from the storage yard without any intervention

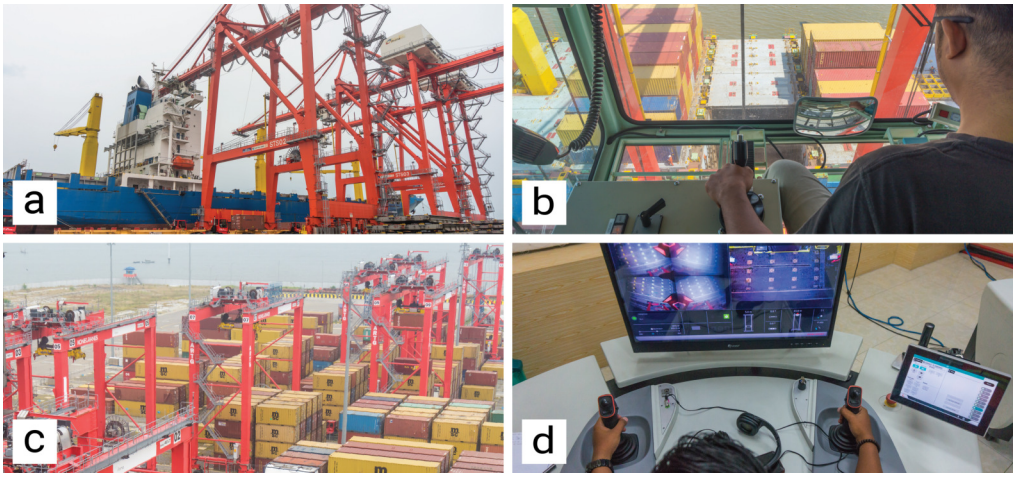

Fig. 1. The cranes employed at the container terminal. (a) The STS cranes used for loading and unloading containers to and from containers ships. (b) The cabin used by the operator to control the STS crane. (c) The ARTG cranes used for moving containers between storage yards and transport vehicles. (d) The remote control station used by the operator to control any of the ARTG cranes within the container terminal.

from operators. Hence, the role of ARTG crane operators was limited to loading and unloading containers to and from transport vehicles, as well as taking over the control of the cranes whenever the cranes could not stack or retrieve containers by themselves. Note that one remote control station (see Figure 1d) could control any ARTG cranes in the container terminal.

4 METHOD

4.1 The Participants

The participants in this study were the crane operators who worked in the container terminal described in Section 3. The container terminal employed a total of 28 crane operators, but there were only eight operators who worked with both types of cranes (see Table 1). Although the eight operators could operate both types of cranes, they only worked with one type of cranes for their regular work shifts (hereinafter referred to as "primary crane"). Depending on the work situation, for example, an absent operator or trying to finish the work before the departure time of the container ship, the eight operators could be requested to work with another type of cranes (hereinafter referred to as "secondary crane"). Therefore, the operators only worked with their secondary crane occasionally.

As shown in Table 1, there were four operators who had the STS cranes as their primary crane and four operators who had the ARTG cranes as their primary crane. All the operators were males and their ages ranged between 24 and 30 years old. Seven operators had at least two years of experience and only one operator who had less than one year of experience. None of the operators previously worked as crane operators before working at this container terminal.

4.2 Data Collection

Eight one-to-one interviews with the operators shown in Table 1 were conducted for this study. Semi-structured interview was selected as the format of the interviews, since it allows the researcher to set the topics of the discussion, while still provides the flexibility to inquire the interviewees' point of view [3]. The interviews were carried out at the

Table 1. The participants' profiles.

Participant number	1	2	3	4	5	6	7	8
Age	25	27	25	24	30	27	29	29
Work experience	2.5 years	2.5 years	9 months	2.5 years	2 years	2 years	2.5 years	2 years
Primary crane	STS	STS	STS	STS	ARTG	ARTG	ARTG	ARTG
Secondary crane	ARTG	ARTG	ARTG	ARTG	STS	STS	STS	STS

container terminal from April 2022 to May 2022 and they were audio recorded. The interviews were done in Indonesian, since that was the language that the operators were comfortable with. The questions asked during the interviews could be grouped into three categories: (1) the operators' background information, e.g., age and work history, (2) things that the operators liked and disliked from operating both types of cranes, and (3) how the operators would mitigate issues that may arise in their work (see the Supplementary Material for the English version of the interview guide). Each interview lasted between 45 and 60 minutes. The protocol of this study was reviewed and approved by Norwegian Centre for Research Data. The operators provided their written informed consent before participating in this study.

4.3 Data Analysis

The data were analyzed based on thematic analysis using the six steps suggested by Braun and Clarke [4]. The first step was to familiarize myself with the data. Here, the audio files from the interviews were transcribed verbatim. The second step was to generate initial codes, in which the transcripts were coded using the NVivo software[1]. Note that the initial codes were generated inductively, as the codes were created to closely describe the content of the data [9]. The third step was to search for themes, where the initial codes were grouped based on their similarities. After grouping the codes, there were four themes that emerged from the data: two themes that represent positive and negative experiences with the STS cranes and another two themes for positive and negative experiences with the ARTG cranes. The fourth step was to review the potential themes by checking if existing themes should be expanded, shrunken, or discarded. After checking the codes again, the operators' experiences seemed to be influenced by two main factors: the work location (in the cabin or in the remote control room) and the level of automation (manual control or semi-autonomous control). Therefore, two subthemes were created for every theme to indicate whether the positive and negative experiences were influenced by the work location or the level of automation. The fifth step was to name the themes and their respective subthemes (see Table 2), while the sixth step was to write the report (see Section 5).

5 RESULTS

This section presents the four themes that have been identified through thematic analysis. Each of the four themes represents either positive or negative experiences that the operators had as the results of working with both types of cranes. Each theme also has two subthemes that indicate how the work location and the level of automation influenced the operators' experiences (see Table 2).

5.1 Positive Experiences with STS Cranes

The operation of the STS cranes is characterized by on-site presence and manual control. Following are the positive experiences that the operators had as the results of working with the STS cranes.

[1]https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Table 2. The factors that positively and negatively influenced the operators' experiences when operating both types of cranes.

Influencing factors	Positive experiences	Negative experiences
On-site presence (STS Cranes)	• Able to see, feel, and respond directly • Having better privacy	• Difficult to visit the toilet • Ergonomic issues inside the cabin • Require more time to reach and leave the cabin • Lack of social interaction inside the cabin
Manual control (STS Cranes)	• Having a challenging job	• Operators' performance is influenced by other workers' performance
Remote presence (ARTG Cranes)	• Having a safer, more comfortable, and more social work environment • Able to work with high flexibility • Having a job that feels like playing a game	• Difficult to handle in case of camera problems • Communication issue between remote operators & drivers of transport vehicles • Visual fatigue from staring at monitors for long hours • Lack of privacy
Semi-autonomous control (ARTG Cranes)	• Having lower workload • Having less liability	• Boredom at work

5.1.1 Able to See, Feel, and Respond Directly. Working from inside the cabin enabled the operators to directly see the work environment and obtain different kinds of information from their surroundings. The presence of such information also enabled the operators to predict what would soon happen and give responses accordingly. Furthermore, as the operators had full control over the STS cranes, they could also adjust their work speed based on the work demand.

5.1.2 Having a Challenging Job. Since the STS cranes were operated manually, the operators considered operating the STS cranes much more difficult and complex than operating the ARTG cranes. However, having a difficult and complex job was perceived positively by the operators, as they felt challenged by their job.

5.1.3 Having Better Privacy. Since the operators worked alone inside the cabin, they did not feel being continuously monitored by other workers, especially by their superiors.

5.2 Negative Experiences with STS Cranes

Following are the negative experiences that the operators had as the results of working from inside a cabin and operating the STS cranes manually.

5.2.1 Difficult to Visit the Toilet. Since the cabin of the STS cranes was not equipped with a toilet, the operators had to go down whenever they wanted to visit the toilet, which also caused the work to be stopped. This situation demanded the operators to plan their toilet visits carefully, so the work would not be delayed significantly. Some of the operators decided to use "creative approaches" in order to reduce their toilet visits.

5.2.2 Ergonomic Issues inside the Cabin. As seen in Figure 1b, the operators constantly looked down when working inside the cabin. The operators admitted that working with such posture over the long term could cause neck strain and back pain.

5.2.3 Require More Time to Reach and Leave the Cabin. As the STS cranes were stationed in the quay, the operators had to spend additional time for reaching and leaving the cabin. Although the STS cranes were equipped with lifts that could easily bring the operators up and down between the cabin and the ground, the operators still felt the travel time to reach and leave the cabin as time consuming.

5.2.4 Lack of Social Interaction inside the Cabin. While working from inside a cabin offered better privacy (see Section 5.1.3), it also prevented the operators from having social interaction with their co-workers. The operators sometimes experienced loneliness when working inside the cabin.

5.2.5 Operators' Performance Is Influenced by Other Workers' Performance. Although one STS crane was controlled by one operator, the STS operation was considered a team work due to the involvement of other workers, e.g., stevedores that helped in the process of loading and unloading containers to and from container ships or drivers of transport vehicles that helped delivering and retrieving containers. The operators sometimes felt dissatisfied when there were problems that happened due to other workers' mistakes, since their performance would decrease as well.

5.3 Positive Experiences with ARTG cranes

The operation of the ARTG cranes is characterized by remote presence and semi-autonomous control. Following are the positive experiences that the operators had as the results of working with the ARTG cranes.

5.3.1 Having a Safer, More Comfortable, and More Social Work Environment. Since the operators worked far from their cranes, they were protected from any accidents that could happen around their cranes. The operators also considered the remote control station of the ARTG cranes (see Figure 1d) comfortable, since they could adjust the height of the remote control station according to what they needed. Moreover, as the operators were working from the same room, they could easily socialize with each other.

5.3.2 Able to Work with High Flexibility. As described in Section 3, one remote control station could operate any of the 12 ARTG cranes. This functionality enabled one operator to easily take over the work that had to be performed by the other operators. The ability to take the work of others allowed the operators to visit the toilet or grab drinks/snacks without stopping the whole operation.

5.3.3 Having Lower Workload. As described in Section 3, the role of ARTG operators in normal circumstances was limited to loading and unloading containers to and from transport vehicles, while the remaining work was done autonomously by the cranes. The operators considered operating the ARTG cranes much easier and far less complex than operating the STS cranes.

5.3.4 Having a Job That Feels Like Playing a Game. The operators felt that operating the ARTG cranes was similar to playing a video game, since the operators could not not feel the impact of their activities and the feedback that they could receive was limited to what was shown on the monitors of the remote control station (see Figure 1d).

5.3.5 Having Less Liability. The transition from manual control to semi-autonomous control also changed who was responsible for an error. In the manual container stacking, the operators were responsible for picking the right container and placing it on the right location. In case of the ARTG cranes, the operators were no longer responsible for incorrect container placement in the storage yard, since their role was limited to loading and unloading containers to and from transport vehicles. In case of incorrect container placement, the blame would go to the planners at the container terminal,

since they were responsible for entering containers' data that the ARTG cranes used to decide which containers to be picked and where they should be placed.

5.4 Negative Experiences with ARTG Cranes

Following are the negative experiences that the operators had as the results of working from a remote control room and working with semi-autonomous cranes.

5.4.1 Boredom at Work. As the side effect of having lower workload (see Section 5.3.3), the operators often felt bored with their work, since loading and unloading containers to and from transport vehicles were considered "too easy" or "not challenging". The operators also found that they generally spent more time waiting for incoming work than performing the work.

5.4.2 Difficult to Handle in Case of Camera Problems. Since the operators were not present on-site, they had to rely on the video stream from the on-site cameras to observe the work environment. However, the video stream was often unclear due to the presence of dust or water droplets on the cameras. Moreover, in case of malfunctioned cameras, it usually took few days for the technicians at the container terminal to install new cameras. The presence of unclear video stream or malfunctioned cameras made the operators' work much more difficult, as they had to rely on the video stream from the remaining cameras and their "instinct" in order to cope with this situation.

5.4.3 Communication Issue between Remote Operators and Drivers of Transport Vehicles. When loading and unloading containers to and from transport vehicles, the operators sometimes had to communicate with the drivers in case of the transport vehicles were not parked in the proper place or the drivers forgot to release the twist locks that secured the container on the vehicle's chassis. However, the communication between the operators and the drivers was designed as a one-way communication, where the drivers could hear what the operators said, but the operators could not hear what the drivers said. To mitigate this issue, the drivers had to make themselves visible in the cameras and relied on body gestures in order to communicate with the operators.

5.4.4 Visual Fatigue from Staring at Monitors for Long Hours. Since the operators relied on the information shown on the monitors to perform their work, they had to frequently stare at the monitors during the eight-hour shift. The operators experienced visual fatigue due to staring at the monitors for long hours.

5.4.5 Lack of Privacy. The remote control room, where the operators were working at, was located in the same building as the other office rooms in the container terminal. Hence, it was easy for other employees to visit the remote control room as they pleased. However, this made the operators feel being continuously watched by other employees.

6 DISCUSSION

The list of positive and negative experiences presented in Section 5 is not meant to be exhaustive. One could expand the list of experiences by interpreting one good experience in one operational mode as a missing experience in another operational mode, and vice versa. However, this was not always the case in this study, since a positive experience in one operational mode was not always expected in another operational mode. For example, the operators considered the ability to see, feel, and respond directly as a positive experience from the STS cranes (see Section 5.1.1), but the lack of sensory experience in remote operation was not viewed as a negative experience from the ARTG cranes. Instead, the fact that the operators could not feel the impact of their activities made operating the ARTG cranes similar to playing a

game (see Section 5.3.4) and this was viewed as a positive experience by the operators. Therefore, the list of positive and negative experiences in Section 5 should be seen as the experiences that the operators paid attention to or concerned about, rather than the list of all possible experiences that the operators could have from operating both types of cranes.

Although the contexts of the related studies are not exactly the same as this study (see Section 2), there are some similarities between the results of this study and the other studies. The ability to see, feel, and respond directly is also reported by Shapira and Elbaz [12] as some of positive experiences of operating a tower crane from inside a cabin. Difficulty to visit the toilet, ergonomic issues inside the cabin, and more time to reach the cabin are also reported as some of negative experiences due to working inside a cabin. With an exception that remote operators could visit the toilet easily, there are no other similar positive experiences between operating the ARTG cranes and the remote tower crane studied in [12], probably because their remote tower crane was still manually controlled and the operator also had to be present near the crane. Similar to this study, Abdullah et al. [2] also investigated the overall experiences due to working with remote container cranes with semi-autonomous control. Lower risk of accidents, better ergonomics, and lower workload were also reported as some of positive experiences of working with remote semi-autonomous container cranes. Except for the difficulty to operate remote container cranes when there are problems with on-site cameras, there are no similarities on the negative experiences. The negative experiences reported in [2] are mostly influenced by technical issues, such as time delay, problem detection, and visual limitation.

Finally, the results of this study further contribute to the broader discussion about the impact of automation on user experience. Cummings et al. [5] argue that incorporating higher level of automation in work settings also increases the level of boredom. The same notion is also found in this study, as the operators often felt bored as the result of having lower workload when operating the ARTG cranes (see Section 5.4.1).

7 CONCLUSION & FUTURE WORK

The objective of this paper was to explore what kinds of experiences that crane operators could have as the results of operating manual container cranes and remote container cranes with semi-autonomous control. Eight crane operators who worked with both operational modes, were interviewed to discover what kinds of experiences that they have. The results suggest that the operators' experiences were positively and negatively influenced by two factors: (1) the location of the operators and (2) the level of automation of the cranes.

Since this study was conducted in one container terminal only, this study was limited to the available cranes in one particular container terminal. Although both STS cranes and ARTG cranes are used for handling containers, they are not exactly the same types of cranes, since they have different forms and purposes. Therefore, it would be interesting to conduct similar studies that specifically compare different operational modes of the same type of cranes to determine to what extent the findings from this study would remain applicable. For example, future studies could specifically compare experiences that operators had from operating manual and remote STS cranes, as well as from operating manual and remote RTG cranes.

ACKNOWLEDGMENTS

This research was funded by the Department of Design, NTNU and the SFI AutoShip Centre (the Research Council of Norway under project number 309230). The author would like to thank the management of the container terminal for giving permission to conduct this study and all the crane operators for their willingness to participate in this study.

REFERENCES

[1] Ummi Noor Nazahiah Abdullah and Heikki Handroos. 2017. Investigation on sense of control parameters for joystick interface in remote operated container crane application. *AIP Conference Proceedings* 1885, 1 (2017), 020077. https://doi.org/10.1063/1.5002271

[2] Ummi Noor Nazahiah Abdullah, Norashiken Othman, Fairuz I. Romli, and Heikki Handroos. 2018. Investigation on user experience goals for joystick interface design. *Journal of Mechanical Engineering* 15, 1 (2018), 133–142. https://ir.uitm.edu.my/id/eprint/36300

[3] William C. Adams. 2015. Conducting Semi-Structured Interviews. In *Handbook of Practical Program Evaluation* (fourth ed.), Kathryn E. Newcomer, Harry P. Hatry, and Joseph S. Wholey (Eds.). John Wiley & Sons, Ltd, Hoboken, NJ, USA, Chapter 19, 492–505. https://doi.org/10.1002/9781119171386.ch19

[4] Virginia Braun and Victoria Clarke. 2012. Thematic analysis. In *APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological*, Harris Cooper, Paul M. Camic, Debra L. Long, A. T. Panter, David Rindskopf, and Kenneth J. Sher (Eds.). APA, Washington, D.C., USA, 57–71. https://doi.org/10.1037/13620-004

[5] Mary L. Cummings, Fei Gao, and Kris M. Thornburg. 2016. Boredom in the Workplace: A New Look at an Old Problem. *Human Factors* 58, 2 (2016), 279–300. https://doi.org/10.1177/0018720815609503

[6] ISO 9241-210. 2019. *Ergonomics of human–system interaction — Part 210: Human-centred design for interactive systems.* International Organization for Standardization, Geneva, Switzerland. https://www.iso.org/standard/77520.html

[7] Hannu Karvonen, Hanna Koskinen, and Jaakko Haggrén. 2012. Enhancing the User Experience of the Crane Operator: Comparing Work Demands in Two Operational Settings. In *Proceedings of the 30th European Conference on Cognitive Ergonomics (ECCE '12).* ACM, New York, NY, USA, 37–44. https://doi.org/10.1145/2448136.2448144

[8] Hanna Koskinen, Hannu Karvonen, and Helena Tokkonen. 2013. User Experience Targets as Design Drivers: A Case Study on the Development of a Remote Crane Operator Station. In *Proceedings of the 31st European Conference on Cognitive Ergonomics (ECCE '13).* ACM, New York, NY, USA, Article 25, 9 pages. https://doi.org/10.1145/2501907.2501956

[9] Mai Skjott Linneberg and Steffen Korsgaard. 2019. Coding qualitative data: A synthesis guiding the novice. *Qualitative Research Journal* 19, 3 (2019), 259–270. https://doi.org/10.1108/QRJ-12-2018-0012

[10] Petros L. Pallis. 2017. Port Risk Management in Container Terminals. *Transportation Research Procedia* 25 (2017), 4411–4421. https://doi.org/10.1016/j.trpro.2017.05.337

[11] Paula Savioja, Marja Liinasuo, and Hanna Koskinen. 2014. User experience: does it matter in complex systems? *Cognition, Technology & Work* 16 (2014), 429–449. https://doi.org/10.1007/s10111-013-0271-x

[12] Aviad Shapira and Avihu Elbaz. 2014. Tower Crane Cycle Times: Case Study of Remote-Control versus Cab-Control Operation. *Journal of Construction Engineering and Management* 140, 12 (2014), 05014010. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000904

[13] Taufik Akbar Sitompul. 2022. Human–Machine Interface for Remote Crane Operation: A Review. *Multimodal Technologies and Interaction* 6, 6 (2022), 45. https://doi.org/10.3390/mti6060045