

Automation of Work Processes and Night Work

Urška Kosem ¹, Mirko Markič ² and Annmarie Gorenc Zoran ^{2,*} 

¹ Triglav Health Insurance Company, Ltd., 6000 Koper, Slovenia; urska.k8@gmail.com

² Faculty of Organisation Studies in Novo Mesto, 8000 Novo Mesto, Slovenia; mirko.markic@guest.arnes.si

* Correspondence: a.zoran@fos-unm.si

Abstract: Background: Automation of production processes is not just a simple replacement of a person in production, but it should lead to the success of an organization and contribute to the sustainable development of society and the natural environment. The aim of our study was to find out whether the level of automation of production processes affects the proportion of night work hours of production workers and whether employers are willing to automate production processes to achieve a lower number of night work hours. Methods: We used a quantitative approach to collect primary data through the survey method. The questionnaire was completed by 502 large and medium-sized manufacturing companies in Slovenia. Results: We found no statistically significant correlation between the level of automation of production processes and the percentage of night work hours of production workers. We also found that the reduction of the proportion of night work does not appear to be the main motivator for the introduction of automation of production processes. Conclusions: Based on the results, we rejected the assumption that automation of production processes has a direct impact on the proportion of night work. Moreover, our study will benefit all those who are concerned with the automation of production processes and night work.

Keywords: automation; future development; Industry 4.0; management; night work; production; processes



Citation: Kosem, U.; Markič, M.; Gorenc Zoran, A. Automation of Work Processes and Night Work. *Data* **2021**, *6*, 56. <https://doi.org/10.3390/data6060056>

Academic Editor: Francisco Guijarro

Received: 12 April 2021

Accepted: 19 May 2021

Published: 26 May 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Industry 4.0 is changing business models in manufacturing. These technologies can support manufacturing flexibility, efficiency, and productivity through various emerging communication, information, and intelligence technologies [1]. Industry 4.0 (I4.0) technologies include additive manufacturing, artificial intelligence, Big Data and analytics, blockchain, cloud, industrial internet of things, and simulation [2].

In both research and industry, it is not yet entirely clear what I4.0 applications as a whole look like and how they might work. For most working in this field, digital transformation and its impact on operational processes remain a big black box. The transformation of manufacturing through technological and paradigmatic drivers is leading to fundamental changes in organizations and processes [3] as well as in human work [4]. Technological change also has far-reaching organizational implications and offers the opportunity to develop new business and corporate models and enable greater employee engagement. I4.0 enables continuous productivity and efficient use of resources across the value network. It allows work to be organized in a way that takes into account demographic change and social factors. In this context, the human factor has received particularly little attention to date, even though it plays a central role in four of the eight I4.0 development focus areas (i.e., management of complex systems, safety and security, work organization and design, and training and professional development), as outlined in the seminal I4.0 report by Kagermann, Walster, and Helbig [5].

I4.0 and technological change are rapidly transforming almost all areas of human life, work, and interaction. These changes are acutely evident in the way human work is organized and performed. The results of the content analysis by Neumann, Winkelhaus,

Grosse, and Glock [6] illustrate the lack of attention paid to the human factor in current I.40 research, which seems to be strongly technology-oriented and only sporadically pays attention to the interaction between humans and systems. To make better and more optimal decisions regarding human resource management in healthcare, we can draw several parallels with manufacturing from a process perspective; organizations collect and process information about employees, their internal policies regarding human resource management, compensation, systematization, performance appraisals, skills, and more [7].

A common speculation about the future is that machines will take over our jobs and make life more convenient and attractive. Today's situation shows the exact opposite: people have never been busier than they are today, and much of the credit for this can be attributed to technology. Through information and communication technology, the world has become interconnected. For the economy, this means a significant breakthrough, which is also linked to the automation of production processes.

Automation of production processes is generally expected to reduce the need for direct human involvement in production work [8]. The risk of automation is mainly in physical activities that are predictable and in cognitive activities such as data collection and processing. In these cases, humans are placed in the role of substituting automation activities to enable the full implementation of these procedures [9]. Many researchers have addressed the question of what risks individual jobs face with respect to the possibility of automation or the replacement of humans by machines. Frey and Osborne [10] concluded in their study that 47% of jobs in the US are at high risk of automation in the next two decades. However, a separate survey of workers for these job types found, somewhat more optimistically, that only 9% of jobs in the US are at risk [11]. Although we could replace mundane and routine tasks originally performed by humans with machines, Autor [12] points out that operational and work requiring less training and skills are not necessarily the ones most at risk of automation. In this regard, Autor points to various service jobs such as catering, maintenance, health care and security where there is a high level of human interaction and usually a high need for flexibility; such jobs are very difficult or impossible to automate. Chui, Manyika, and Miremadi [9] found that the main characteristic that makes individual tasks or jobs more susceptible to automation is predictability, which makes manufacturing one of the most vulnerable areas. A study conducted on a sample of more than 800 occupations in the US showed that in manufacturing alone, up to 59% of the jobs currently performed by workers could be automated [9]. Accordingly, further research shows that the smallest job losses were in retail, at 7%, while the largest losses occurred in manufacturing, where the number of jobs fell by a third [13].

Although there has been a manufacturing trend in the last century to introduce factories with complete process automation, most are only partially automated, i.e., combinations of automated and manual tasks [14]. Complete automation of work processes is the degree to which, for example, robots, intelligent manufacturing cells, automated material control systems, and computer control mechanisms are recognized to produce products without human supervision and intervention [15]. Stevenson [16] and Satchell [17] define automation as the replacement of human activities with activities performed by a machine, and Rozman [18] adds that machines also take control of activities. Automation is when a production system, process, or device or tool performs tasks autonomously and controls itself [19]. Thurman, Brann, and Mitchell [20] divide automation into two areas: Mechanization, which refers to the automation of physical tasks, and Computerization, which refers to the automation of cognitive tasks. Automation has the potential to restructure the vast majority of existing jobs and therefore entire work processes [9]. Advances in technology and process automation are responsible for the trend of disappearance of undemanding, medium paying jobs and the emergence of new, more demanding and better-paying jobs [21]. The use of Big Data now enables organizations to collect and combine a large amount of data from various sources, organize and store those data, and then analyze them to make the most optimal decisions [22]. The use of Big Data solutions is not universal and depends on the variability and complexity of the production systems [23].

To distinguish between more and less automated factories, systems, processes, tasks, and the like, the term “level of automation” (LoA) is used. It is the distribution of physical and cognitive tasks between humans and technology, characterized on a continuum from complete non-automation to complete automation [24]. Research has only recently begun to focus extensively on measuring the level of automation in production systems. The development of a method for measuring the degree of automation in production systems was pioneered in Sweden in 2004–2007 and was named DYNAMO (Dynamic Levels of Automation) methodology, which proceeds in eight steps [25].

While the literature mostly mentions only three levels of automation with the two extremes and one intermediate level, partial automation, there are also more detailed levels, e.g., ten levels of automation by Sheridan and Verplanck [26], who define as the lowest level not the complete absence of automation but a certain degree of human–computer cooperation. Different authors have defined their view of the level of automation. For example, Satchell [17] defined the level of automation as the cooperation between humans and machines with varying degrees of human involvement. Amber and Amber [27] defined the level of automation as the degree to which machines replace human influence and control over production processes. Parasuraman and Riley [28] asserted that it is a scale from manual to completely automated processes. Additionally, Groover [29] defined automation level as the extent of human control over a machine, which can be completely manual, semi-automated, or completely automated. Ruff, Narayanan, and Draper [30] also defined three levels of automation. Milgram, Rastogi, and Grodski [31] defined five levels of automation related to the control of technology and machines in the field of telerobotics. Frohm and colleagues [32] also proposed two separate LoA scales: the seven-level scale for mechanization tasks and the seven-level scale for computerization tasks. Based on the above taxonomies, we note that authors disagree on the number and descriptions of each automation level. The suspected reason for this is that the authors come from different backgrounds, and the classification of automation levels was done for different reasons (some did not even give a specific definition), taking into account different aspects.

In connection with the automation of production, the term lights-out automation or lights-out production is also mentioned in the literature. Parallel to the general definition of automation, it is a technology that performs certain tasks instead of a worker [33]. The advantage of lights-out production systems is said to be the ability to produce at night without human presence, which means savings in energy and labor costs, and that workers can focus on more complex tasks during the day [34]. Due to the savings, Wolfgang et al. [35] highlighted the potential of night shift automation as a strategic innovation in manufacturing and proposed splitting production into two shifts: a day shift for employees and a night shift for robots only. Löfving et al. [36] stated that due to the desire to automate evening and night shifts to improve productivity, there is an increasing demand in manufacturing companies for technological solutions that enable a continuous production process without human intervention for at least one whole shift.

Night work is most common in healthcare, industrial manufacturing, mining, transportation, communications, hospitality, and tourism [37]. Despite the financial and other benefits and special protections that employers are legally obligated to provide, these legal obligations often do not outweigh the reasons for implementing a night shift. These reasons can be divided into three groups: organizational, technical, and economic. In many cases, night work is necessary, especially when the health and safety of the public is at stake (e.g., emergency and health services; hospitals, homes, and similar institutions; firefighters, police, security, and other related services). In these activities, it can be said that there are organizational reasons for night work. Here, services have to be provided continuously, which cannot be solved otherwise than by being on call at the workplace all the time. Technical reasons for the introduction of night work occur most often in manufacturing, metallurgy, and chemical and food industries [38], where it is usually impossible to stop the operation of equipment or machinery, interrupt a particular process, or perform a particular activity. Economic reasons for introducing night work include any reason that

improves the financial situation of the employer. These reasons range from increasing customer orders to maximizing the use of new, more expensive devices or equipment with which to gain a competitive edge. Economic reasons, combined with the negative effects of night work on the health and lives of individuals, are often strongly condemned and described as unjustifiable reasons for introducing such work [38,39].

Shift work, especially night shift work, is often associated with various health problems. Numerous studies have shown a strong association between shift work and the occurrence of various diseases and health disorders [40] and reproductive issues [41]. This type of work is also associated with the occurrence of occupational accidents [42]. Night work is a more demanding type of work; therefore, the worker is entitled to special rights and benefits [43]. Thierry [44] found that instead of compensation for shift work, it makes more sense to limit or eliminate shift work.

Based on the review of literature and findings, we formulated the following hypotheses:

Hypothesis 1. *There is a negative correlation between the level of automation of production processes and the proportion of hours worked by production workers during the night shift (the higher the level of automation, the less night work).*

Hypothesis 2. *Reducing the amount of night work does not appear to be a key motivator for introducing automation of production processes.*

After reviewing the theoretical starting points on automation of production processes and its impact on human night work, we found that the topic is current and deserves the attention of theorists and researchers worldwide. Although the relationship between automation and night work reduction is apparent, this relationship has not yet been empirically investigated. We found no studies on the relationship between the level of automation and the reduction of night work hours, which is an identified research gap. The objective of our study was to determine whether the degree of automation of production processes affects the proportion of night hours worked by production workers and whether employers are willing to automate production processes to achieve a lower proportion of night work.

2. Materials & Methods

A quantitative approach was used as a general guide, using the survey method described by Easterby-Smith, Thorpe, and Lowe [45]. A questionnaire was used to collect the primary data.

The questionnaire consisted of a combination of closed and open-ended questions. It was designed in such a way that in the first stage, the companies were separated to determine whether the respondents performed night shifts in production. This excluded those that did not have night shifts in their production. Then, the companies that were conducting night shifts at the time of the survey were asked to provide a reason for the night shifts. Based on this, in the second set of questions we used a rating scale from 1 (fully manual) to 5 (fully automated) to determine the level of automation of the production processes. We used the five different operations or tasks in the production system of Ljubič [46] and Kaltnekar [47]. These are: (1) processing; (2) transportation; (3) storage; (4) control and management, and (5) bottlenecks/shutdowns in production. In relation to these activities, we also asked the respondents about the extent of night work in each activity. All companies, both those that had night shifts and those that did not, were asked about specific motivators they would be willing to invest resources in to achieve higher levels of process automation, or they were asked about motivators they had in the past. In the last part of the questionnaire, we asked all participating companies to provide demographic information, such as occupation and number of employees in the production process.

The population was medium and large industrial enterprises in the Republic of Slovenia with at least 50 employees. We used the Standard Classification of activities in

the Republic of Slovenia (SKD) [48] to identify enterprises or organizations classified as industrial production (N.B. SKD is based on the EU Economic Activity Classification). Most of the production activities were classified in category C—Manufacturing, so we determined the registered production activity according to SKD as a restriction and criterion for the selection of units in the population.

The results of the Gvin database [49] showed 381 medium-sized and 135 large enterprises in Slovenia that were active and registered in the manufacturing sector on 27 May 2019 (Gvin.com). We then examined publicly available data and excluded firms that had no active manufacturing or employed fewer than 50 people. The population was thus 502 large and medium-sized manufacturing firms in Slovenia with at least 50 employees.

We emailed the questionnaire to all companies in our population, targeting production managers or employees in similar positions. We then processed the collected data, analyzed them, and interpreted the results. Specifically, we performed descriptive statistics on company demographics and compared data on the level of automation of individual activities using Pearson's correlation coefficient with the proportion of hours that production employees worked on during the night shift. In this way, we attempted to determine the possible relationship between the two factors and to test the first hypothesis. For the second hypothesis, we used descriptive statistical analysis—namely, we analyzed the frequency of night work reduction as a motivator for automation of production processes compared with other listed motivators.

3. Results

3.1. Demographic Information

Questionnaires were distributed to all companies that met the inclusion criteria, and a response rate of 23.1% ($n = 116$ companies) was obtained.

Table 1 shows the demographic information of the surveyed companies on night shifts, number of employees in production, and activity by SKD classification.

More than two-thirds of all respondents ($n = 79$) answered that they had a night shift in production.

It is possible that the invitation to participate in the survey contributed to a slight increase in the number of companies with night shifts. This is because the topic (i.e., automation of production processes associated with night work) was already mentioned in the subject of the email when addressing the participants. In this respect, it is possible that a slightly larger number of companies with night shifts responded to the invitation, even though we invited everyone to participate. We cannot determine whether the sample is significantly different from the population because there are no publicly available databases with data on night work in firms that meet the criteria of our population.

The surveyed firms had an average of 185.6 employees in their production systems, with the firm with the highest number having 1305 employees. If we exclude from the calculation 37 companies from which we did not receive a response, most of the companies, i.e., 77.22%, rank first by the number of employees—namely, from 0 to 249 employees. In second place, 15.19% rank up to and including 499 employees, and only 7.59% of the companies rank up to 1500 employees.

The first five activities that most companies in the sample were engaged in (37 respondents did not answer) were:

1. C25 manufacture of fabricated metal products, except machinery and equipment;
2. C22 manufacture of rubber and plastic products;
3. C23 manufacture of non-metallic mineral products;
4. C10 food production;
5. C27 manufacture of electrical equipment.

The remaining ten manufacturing activities that the respondents noted represented 26% of the total structure, while for 13% of the responses, activities could not be defined according to SKD due to overly general responses (e.g., “production”, “assembly”).

Table 1. Number of enterprises by different characteristics.

	Frequency	Proportion (%)
Running a night shift		
Yes	79	68.10
No	37	31.90
Total	116	100.00
Number of employees in production		
0–249	61	52.59
250–499	12	10.34
500–749	2	1.72
750–999	2	1.72
1000–1249	1	0.86
1250–1500	1	0.86
No answer	37	31.90
Total	116	100.00
SKD Activity		
Manufacture of fabricated metal products, except machinery and equipment	16	13.79
Manufacture of rubber and plastic products	10	8.62
Manufacture of non-metallic mineral products	10	8.62
Manufacture of food products	7	6.03
Manufacture of electrical equipment	5	4.31
Manufacture of basic metals	4	3.45
Manufacture of other machinery and equipment	4	3.45
Manufacture of chemicals and chemical products	3	2.59
Manufacture of paper and paper products	2	1.72
Manufacture of motor vehicles, trailers, and semi-trailers	2	1.72
Manufacture of textiles	1	0.86
Manufacture of leather, leather and related products	1	0.86
Printing and reproduction of recorded media	1	0.86
Manufacture of other transport equipment	1	0.86
Other miscellaneous manufacturing	1	0.86
Repair and installation of machinery and equipment	1	0.86
Cannot be determined	10	8.62
No answers	37	31.9
Total	116	100.00

3.2. Hypotheses Testing

Hypothesis 1. *There is a negative correlation between the level of automation of production processes and the proportion of hours worked by production workers during the night shift (the higher the level of automation, the less night work).*

For this purpose, two data elements were analyzed at the level of the individual production system:

- the level of automation of the production processes;
- the percentage of human/hours worked during the night shift in the production system, relative to the volume of human/hours worked during the entire workday (all 24 h).

The relationship between these two factors was analyzed using Pearson's correlation coefficient. For each production system, we calculated the level of automation from 1 (fully manual) to 5 (fully automated) and the proportion of night work as a percentage. To do this, for each production system, we collected and evaluated estimates of levels of automation for five or six groups of activities and the proportion of human labor during the day and night shifts for each of these activities.

To obtain an overall estimate of the level of automation of production processes in a single system, we could have added the estimates for each activity and divided the

obtained number by the number of activities. Such a calculation would give equal weight to all estimates. Consequently, we would have neglected one of the critical arguments we discussed earlier—namely, the very definition of automation, which, in summary, is the replacement of human tasks by tasks performed by a machine. Therefore, we weighted activities that require more human labor higher than those that require less. The reason for this is that it is logical to assume that achieving a certain level of automation with a currently larger volume of human labor requires a more extensive introduction of automation than achieving the same level with a currently smaller volume of labor. Therefore, the individual values at the activity level were weighted by the coefficient of the ratio of human labor in that activity to human labor in the entire production system, and only then was the total value calculated. We formulated this as an equation (see Figure 1), where *LoA* is the calculated level of automation, *s* is the estimated level of automation of each activity, *d* is the scope of human labor or the number of human/hours worked for a single activity, and the numbers from 1 to 5 denote the individual activities.

$$LoA = \frac{\sum_{i=1}^5 s_i d_i}{\sum_{i=1}^5 d_i}$$

LoA – Level of Automation
s – Level of automation of each activity
d – Scope of human work on an activity
 1 to 5 – Activities

Figure 1. Level of Automation Formula.

We could apply this equation only in cases where we obtained all data for all five activities. None of the estimated levels of automation for a given activity was given a score of 5—fully automated—because for truly fully automated activities, the need for human labor should not occur frequently. Therefore, these ratings were assigned a uniform weighting according to the total number of activities.

To graph the data and calculate Pearson’s correlation coefficient, we obtained the “complete” scores based on the units in the sample where all required fields were filled in, while we also included “incomplete” scores. The latter were based on items in the questionnaires that were not fully completed (e.g., missing rate information despite the number of hours worked, or vice versa—these activities were excluded from the calculation of the total score) or on certain combinations of answers that were illogical (e.g., indicating a certain amount of human labor despite the assessment that it was full automation). For example, for a score of 5 indicating the amount of human labor, we considered 4.5 instead of 5 because we assumed that respondents wanted to indicate that there was an extremely high level of automation despite human labor, for which a score of 4 (mostly automated) would be too low. Among the incomplete scores, we also included the only case in which one of the activities was rated as fully automated. As described above, we used a slightly adjusted method to calculate the total score.

The following graph (Figure 2) shows the overall score of the level of automation of each production system relative to the amount of night work for both complete and incomplete scores. Even after a brief observation, it can be assumed that there is no correlation between the factors considered, as the data are scattered throughout the field and a direction of movement is not apparent.

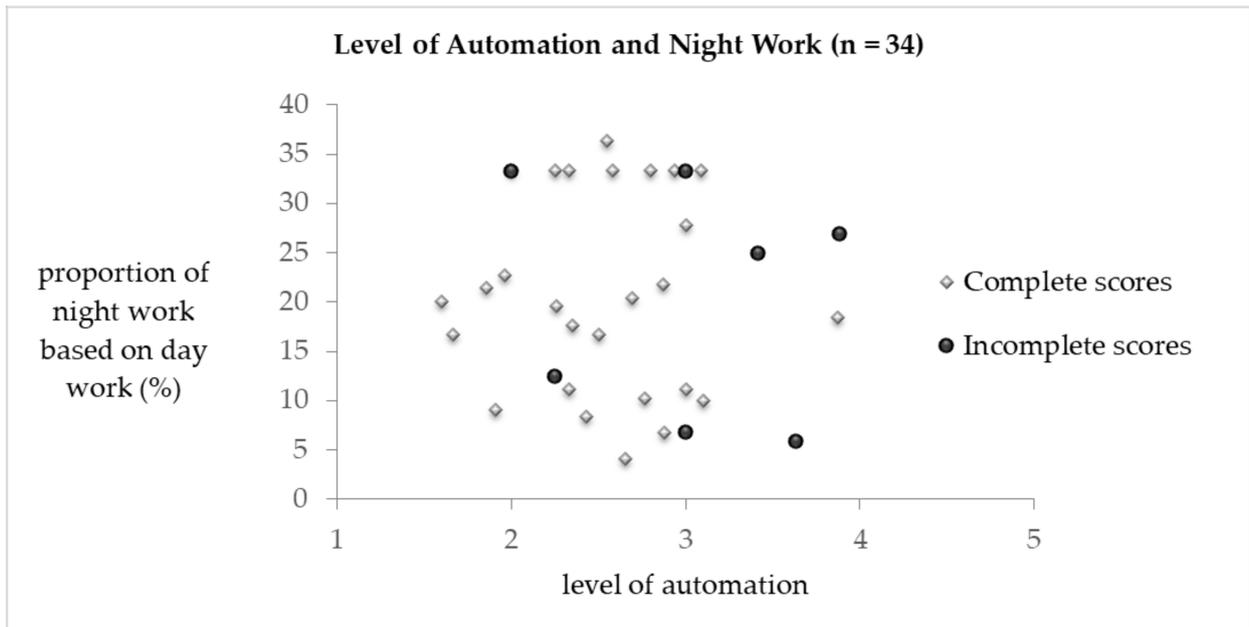


Figure 2. Level of Automation and Proportion of Night Work.

To confirm our assumption, we also calculated Pearson’s correlation coefficient (r) for both complete and for all scores (i.e., complete and incomplete; see Table 2).

Table 2. Pearson’s Correlation Coefficient on the Level of Automation and Night Work.

	Complete Ratings	All Ratings
n	27	34
r	−0.0124	−0.0569

Both coefficient values have a negative sign, which indicates that it is a negative correlation, and based on our hypothesis, the higher the level of automation, the less night work can be confirmed, but the value of the coefficient needs to be considered with Pearson’s correlation coefficient. In both cases, these are extremely low absolute values, which means a slight correlation. As such, we rejected the hypothesis.

Hypothesis 2. *Reducing the amount of night work does not appear to be a key motivator for introducing automation of production processes.*

To confirm this hypothesis, two conditions must be met: (1) the motive for limiting shift or night work should not appear as the predominant motive for automating production processes with the remaining responses from the respondents, and (2) the motive of limiting shift or night work should not appear by any of the respondents as the only motive for automating the production processes.

To test this hypothesis, we used the data only from those respondents who answered “Yes” to whether they were currently running a night shift. To the question, where respondents could offer multiple responses or by adding responses, we measured the frequency of motives for the automation of production processes, or in other words, the purposes and goals for which organizations would be willing to invest (or have invested) in automation. The incidence of individual responses is shown in Figure 3 (where n is equal to the number of companies responding to this question).

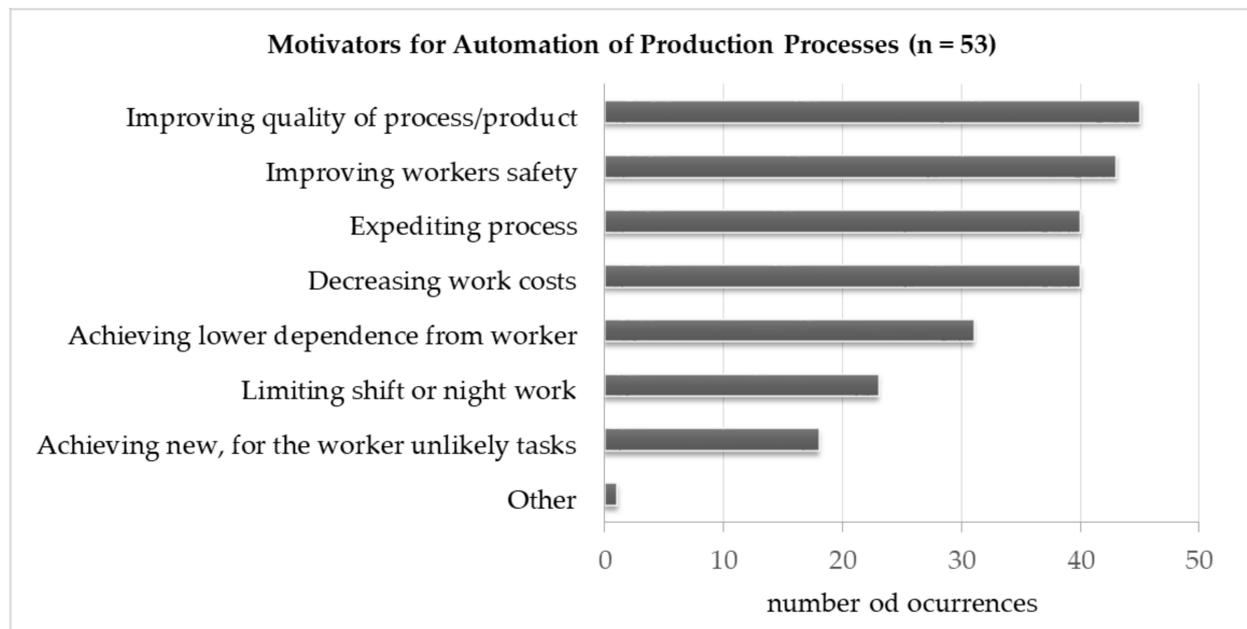


Figure 3. Motivators for Automation in Companies that Run the Night Shift.

From the results in Figure 3, we see that the highest frequency of responses regarding top priority or motives for introducing automation in the production system were for improving the quality of the process or product and improving workers safety. These were followed by expediting the process and decreasing labor costs. The motive that interested us the most was limiting shift or night work. According to Figure 3, limiting night or shift work is a motive that occurs less frequently compared with others, coming almost second to last from “Achieving new, for the worker unlikely tasks”. The motivators on limiting shift or night work in relation to the frequency of indications, therefore, occurred less frequently, thus fulfilling the first condition:

1. A motivator for limiting shift or night work does not appear as the predominant motivator for automating production processes relative to the respondents’ remaining responses.

By reviewing individual questionnaires, we also found that the motivator for limiting shift or night work always appears in combination with other motivators or that none of the respondents chose this motivator as the only motivator for automating production processes, thus fulfilling the second condition:

2. A motivator for limiting shift or night work does not appear by any of the respondents as the only motivator for automating production processes.

We can accept the second hypothesis and conclude that the motivator for reducing night work does not appear as a key motivator for automating production processes in Slovenian manufacturing companies.

4. Discussion and Conclusions

The purpose of our study was to determine whether the level of automation of production processes affects the proportion of night hours performed by production workers and whether employers are willing to automate production processes to achieve a lower proportion of night work. A total of 116 companies, or 23.1% of all the companies we contacted, participated in our survey.

To measure the level of automation of production processes, it was first necessary to identify the type of implementation. So far, no attempts have been made to measure the level of automation of production processes, which would lead to a joint assessment of

the automation of the production system that could be applied directly. To this end, we developed a method for measuring the level of automation based on five general groups of activities in the production system, estimates of the levels of automation of these activities by production managers, and the amount of human labor. To calculate the overall estimate of the level of automation of production processes in each company or production system, we collected data on the level of automation and the scope of human labor at the level of each group of activities. In addition, we examined another variable, night work, for which we also collected data on the volume at the level of each group of activities.

We could not accept the first hypothesis, which found a negative correlation between the level of automation of production processes and the proportion of night work. Although the calculated correlation coefficient is negative and could confirm the hypothesis, it is too low to indicate a significant relationship. We therefore concluded that the two factors were not related. The second hypothesis was confirmed: Reducing the volume of night work does not seem to be among the main motivators for adopting automated production processes. Thus, we rejected one hypothesis and confirmed the other. If there was, or is, a combination of factors that, to some extent, successfully reduce the volume of night work with the automation of production processes, this would most likely indicate that employers are aware of the potential of automation to limit night work and are using it for this purpose. Thus, limiting night work could emerge as one of the main motivators for automation in manufacturing. This would also mean that in this case, one hypothesis is accepted and the other rejected, which further means that we have placed a slightly contradictory hypothesis at the beginning. Overall, no research has been found by the authors on the impact of automation on reducing night shift work and therefore the issue was determined to be a research gap. However, the results of this study differ from and are similar to the results of published studies that have examined the effects of work process automation and night work. The results of our study are related to the findings of Wang and colleagues [50] in their study on the effects of information and communication technology (ICT) on individuals. They evaluated 83 empirical studies and identified two categories of factors that moderate the impact of ICT use on work design—namely, (1) user–technology fit factors and (2) social–technology fit factors. Both are critical factors in work design processes in which night work and the role of automation play an integral part. The results of our study also support the findings previously published by Proper et al. [51], who found that approximately one-fifth of employees in industrialized countries work some form of shift schedule that negatively affects health and increases the risk of illness, and that individuals who are forced to work at a non-standard time (e.g., night shift) that does not coincide with their personal internal clock tend to develop “social jet lag”. On the other hand, Kaasinena [52] notes that the night shift was less hectic than other shifts and that this was because the lighter work tended to be scheduled at night. The findings of this study are also consistent with findings from other industries such as construction [53], agriculture [54], and healthcare [55], all of which are difficult to automate to reduce night work. Folkard and Tucker [39] advocated the abandonment of night work and suggested that all the advantages and disadvantages of this form of work should be examined. Weaknesses in health are noticeable, e.g., sleep disorders, cardiovascular disease, metabolic disorders, fatigue [56], and increased incidence of breast cancer in women [57]. Nevertheless, based on publicly available statistics, which are briefly presented below, we can conclude that Slovenia cannot expect a significant decrease in night work in the near future. According to the latest Eurostat data from 2020 [58], 6.8% of workers in the 27 countries of the European Union (EU 27) are occasionally assigned to a night shift, which is 0.8 percentage points less than the average of the previous decade (2010–2019), during which the trend did not change significantly. For workers regularly assigned to night shifts in the EU 27, the data show a slow but somewhat more even decline in night work, from 6.8% in 2010 to 4.5% in 2020. According to the 2020 data, the share of Slovenian workers who occasionally work night shifts is 10.7%, while the share of workers who regularly work night shifts is 7.9%. In the group of workers who occasionally work night shifts, there

was a slightly larger decrease in the share of night shift workers in the last year compared with the previous year, similar to the EU 27 by 1.3 percentage points. In the long term, there has been a slight decrease in occasional night work. In the group of employees who regularly work at night in Slovenia, the trend of night work continues to increase slowly on a longitudinal basis, despite the decrease in night work in 2020, in contrast to the EU 27. We have gained new knowledge through empirical research that did not exist before and that is a novelty in this field. With the original findings from the conducted survey, we rejected the assumption that automation of production processes has a direct impact on the proportion of night work.

It would also be useful to investigate why employers do not include the reduction of night shift work among the main motivators for the adoption of production process automation. We have found in this study that these two factors are not related at all. Are employers aware of this, and if so, is the prevalence of this motivator lower? It would be useful for further research to investigate the benefits or positive effects of automation in the opinion and experience of employers.

By reviewing the relevant theory and conducting the study, we concluded that night work is a subjective variable that depends on several other variables that vary from company to company. To gain better insight into possible solutions for limiting night work, it would be useful to design any further research as a qualitative research approach, with the individual production system as the primary research unit.

At the same time, interviews with employers could explore their views on the delegation of night work. Only in this way can we better understand the field of night work as well as where and how it makes the most sense to look for solutions—are they technical (e.g., process automation, as we have assumed in our research), organizational, or managerial priorities and values in terms of financial and non-financial effects.

Research on automated production processes and night work would also help other non-production activities. Nevertheless, this type of work is necessary and unavoidable, such as in health care, trade and commerce, the police, the media, and the military.

Author Contributions: The authors U.K., M.M., and A.G.Z. contributed equally. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The present study's data were derived from official information by SKD and Gvin. Data from the questionnaire are available with the author U.K.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ibarra, D.; Ganzarain, J.; Igartua, J.I. Business Model Innovation through Industry 4.0: A Review. *Procedia Manuf.* **2018**, *22*, 4–10. [[CrossRef](#)]
2. Dalenogare, L.S.; Benitez, G.B.; Ayala, N.F.; Frank, A.G. The Expected Contribution of Industry 4.0 Technologies for Industrial Performance. *Int. J. Prod. Econ.* **2018**, *204*, 383–394. [[CrossRef](#)]
3. Matt, C.; Hess, T.; Benlian, A. Digital Transformation Strategies. *Bus. Inf. Syst. Eng.* **2015**, *57*, 339–343. [[CrossRef](#)]
4. Kadir, B.A.; Broberg, O.; da Conceição, C.S. Current Research and Future Perspectives on Human Factors and Ergonomics in Industry 4.0. *Comput. Ind. Eng.* **2019**, *137*, 106004. [[CrossRef](#)]
5. Kagermann, H.; Wahlster, W.; Helbig, J. *Recommendations for Implementing the Strategic Initiative Industrie 4.0*; National Academy of Science and Engineering: Munchen, Germany, 2013.
6. Neumann, W.P.; Winkelhaus, S.; Grosse, E.H.; Glock, C.H. Industry 4.0 and the Human Factor—A Systems Framework and Analysis Methodology for Successful Development. *Int. J. Prod. Econ.* **2021**, *233*, 107992. [[CrossRef](#)]
7. Sousa, M.J.; Pesqueira, A.M.; Lemos, C.; Sousa, M.; Rocha, Á. Decision-Making Based on Big Data Analytics for People Management in Healthcare Organizations. *J. Med. Syst.* **2019**, *43*, 290. [[CrossRef](#)]
8. Kaltnekar, Z. Production Management. In *Operational Management*; Florjančič, J., Ed.; Modern Organization: Kranj, Slovenia, 1995.
9. Chui, M.; Manyika, J.; Miremadi, M. Four Fundamentals of Workplace Automation. *McKinsey Q.* **2015**, *29*, 1–9.

10. Frey, C.B.; Osborne, M.A. The Future of Employment: How Susceptible Are Jobs to Computerisation? *Technol. Forecast. Soc. Chang.* **2017**, *114*, 254–280. [CrossRef]
11. Arntz, M.; Gregory, T.; Zierahn, U. *The Risk of Automation in OECD Countries*; OECD Social, Employment and Migration Working Papers, No. 189; OECD Publishing: Paris, France, 2016. [CrossRef]
12. Autor, D.H. Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *J. Econ. Perspect.* **2015**, *29*, 3–30. [CrossRef]
13. ILO. *Changing Business and Opportunities for Employers' and Business Organizations*; International Labour Office: Geneva, Switzerland, 2019.
14. Frohm, J. *Levels of Automation in Production Systems*; Chalmers University of Technology: Gothenburg, Sweden, 2008. [CrossRef]
15. Shaiken, H. The Automated Factory: The View from the Shop Floor. *Technol. Rev.* **1985**, *88*, 16–27.
16. Stevenson, W. *Production/Operations Management*; Richard D. Irwin: Chicago, IL, USA, 1996.
17. Satchell, P. *Innovation and Automation*; Ashgate: Aldershot, UK, 1998.
18. Rozman, R. Process planning. In *Production Management: Efficient Process Management in Production and Service Organizations: Lecture Notes*; Dolinšek, S., Rozman, R., Eds.; Faculty of Management Koper: Koper, Slovenia, 2006.
19. Ritzman, L.; Krajewski, L. *Foundations of Operations Management*; Pearson Education, Inc.: New Jersey, NJ, USA, 2003.
20. Thurman, D.; Brann, D.; Mitchell, C. An Architecture to Support Incremental Automation of Complex Systems. In Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics, Orlando, FL, USA, 12–15 October 1997. [CrossRef]
21. Rotman, D. How Technology is Destroying Jobs. *MIT Technol. Rev.* **2013**, *16*, 28–35.
22. Chen, M.; Mao, S.; Liu, Y. Big Data: A Survey. *Mob. Netw. Appl.* **2014**, *19*, 171–209. [CrossRef]
23. Kozjek, D. Information Support Framework for Processes in Manufacturing Systems Based on Big Data. Doctoral Dissertation, University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia, 2019.
24. Fasth, Å.; Stahre, J.; Dencker, K. *Measuring and Analyzing Levels of Automation in an Assembly System. Manufacturing Systems and Technologies for the New Frontier*; Springer: London, UK, 2008.
25. Granell, V.; Frohm, J.; Bruch, J.; Dencker, K. Validation of the DYNAMO Methodology for Measuring and Assessing Levels of Automation. In Proceedings of the Swedish Production Symposium, Gothenburg, Sweden, 28–30 August 2007.
26. Sheridan, T.; Verplanck, W.L. *Human and Computer Control of Undersea Teleoperators*; Massachusetts Institute of Technology: Cambridge, UK, 1978.
27. Amber, J.S.; Amber, P.S. *The Anatomy of Automation*; Prentice Hall: Englewood Cliffs, NJ, USA, 1962.
28. Parasuraman, R.; Riley, V. Humans and Automation: Use, Misuse, Disuse, Abuse. *Hum. Factors* **1997**, *39*, 230–253. [CrossRef]
29. Groover, M.P. *Automation, Production Systems, and Computer-Integrated Manufacturing*, 3rd ed.; Pearson International Edition: London, UK, 2001.
30. Ruff, H.; Narayanan, S.; Draper, M. Human Interaction with Levels of Automation and Decision-Aid Fidelity in the Supervisory Control of Multiple Simulated Unmanned Air Vehicles. *Presence Teleoperators Virtual Environ.* **2002**, *11*, 335–351. [CrossRef]
31. Milgram, P.; Rastogi, A.; Grodski, J. Telerobotic Control Using Augmented Reality. In Proceedings of the 4th IEEE International Workshop on Robot and Human Communication, Tokyo, Japan, 5–7 July 1995. [CrossRef]
32. Frohm, J.; Lindström, V.; Stahre, J.; Winroth, M. Levels of Automation in Manufacturing. *Ergon. Int. J. Ergon. Hum. Factors* **2008**, *30*, 1–28.
33. Brann, D.; Thurman, D.; Mitchell, C. Human Interaction with Lights-out Automation: A Field Study. In Proceedings of the 3rd Annual Symposium on Human Interaction with Complex Systems, Dayton, OH, USA, 25–28 August 1996; pp. 276–283. [CrossRef]
34. Eddy, M. Checklist for Lights-Out Manufacturing. *Production Machining*, 19 December 2013. Available online: <https://www.productionmachining.com/articles/checklist-for-lights-out-manufacturing> (accessed on 7 March 2021).
35. Wolfgang, M.; Lukic, V.; Sander, A.; Martin, J.; Küpper, D. Gaining Robotics Advantage. *BCG Group*. 14 June 2017. Available online: <https://www.bcg.com/publications/2017/strategy-technology-digital-gaining-robotics-advantage> (accessed on 24 April 2021).
36. Löfving, M.; Almström, P.; Jarebrant, C.; Wadman, B.; Widfeldt, M. Evaluation of Flexible Automation for Small Batch Production. *Procedia Manuf.* **2018**, *25*, 177–184. [CrossRef]
37. Straif, K.; Baan, R.; Grosse, Y.; Secretan, B.; Ghissassi, F.E.; Bouvard, V.; Altieri, A.; Benbrahim-Tallaa, L.; Coglianò, V. Carcinogenicity of Shift-Work, Painting, and Fire-Fighting. *Lancet Oncol.* **2007**, *8*, 1065–1066. [CrossRef]
38. Bilban, M. Nočno Delo in Vpliv Na Zdravje. *Delo. Varnost* **2013**, *58*, 42–54.
39. Folkard, S.; Tucker, P. Shift Work, Safety and Productivity. *Occup. Med.* **2003**, *53*, 95–101. [CrossRef]
40. Knutsson, A. Health Disorders of Shift Workers. *Occup. Med.* **2003**, *53*, 103–108. [CrossRef]
41. Mengeot, M.-A. *Production and Reproduction: Places of Health for Future Generations*; Association of Free Trade Unions of Slovenia: Ljubljana, Slovenia, 2009.
42. Costa, G. The Impact of Shift and Night Work on Health. *Appl. Ergon.* **1996**, *27*, 9–16. [CrossRef]
43. Dobrin, T. Part-Time Employment. *Company and Work. J. Econ. Labor. Soc. Law* **1992**, *2*, 110–125.
44. Thierry, H. Compensation for shiftwork: A model and some results. In *Studies of Shiftwork*; Colquhoun, W.P., Rutenfranz, J., Eds.; Taylor & Francis: London, UK, 1981; pp. 449–462.

45. Easterby-Smith, M.; Thorpe, R.; Lowe, A. *Research in Management*; Faculty of Management, University of Primorska: Koper, Slovenia, 2005.
46. Ljubic, T. *Production Planning and Management*; Moderna Organizacija Publishing House within FOV: Ljubljana, Slovenia, 2000.
47. Kaltnekar, Z. *Organization of Work Processes*; Modern Organization within VŠOD Kranj: Kranj, Slovenia, 1996.
48. Statistical Office of the Republic of Slovenia. SKD Classifications. Available online: <https://www.stat.si/statweb/en/methods/classifications> (accessed on 6 February 2019).
49. Gvincom. *Advanced Search Engine*; Bisnode: Ljubljana, Slovenia, 2019.
50. Wang, B.; Liu, Y.; Parker, S.K. How Does the Use of Information Communication Technology Affect Individuals? A Work Design Perspective. *Acad. Manag. Ann.* **2020**, *14*, 695–725. [[CrossRef](#)]
51. Proper, K.I.; Van De Langenberg, D.; Rodenburg, W.; Vermeulen, R.C.H.; Van Der Beek, A.J.; Van Steeg, H.; Van Kerkhof, L.W.M. The Relationship between Shift Work and Metabolic Risk Factors: A Systematic Review of Longitudinal Studies. *Am. J. Prev. Med.* **2016**, *50*, e147–e157. [[CrossRef](#)]
52. Kaasinen, E.; Schmalfuß, F.; Öztürk, C.; Aromaa, S.; Boubekeur, M.; Heilala, J.; Heikkilä, P.; Kuula, T.; Liinasuo, M.; Mach, S.; et al. Empowering and Engaging Industrial Workers with Operator 4.0 Solutions. *Comput. Ind. Eng.* **2020**, *139*, 105678. [[CrossRef](#)]
53. Guven, G.; Ergen, E. A Rule-Based Methodology for Automated Progress Monitoring of Construction Activities: A Case for Masonry Work. *J. Inf. Technol. Constr.* **2019**, *24*, 188–208.
54. Lunner-Kolstrup, C.; Hörndahl, T.; Karttunen, J.P. Farm Operators' Experiences of Advanced Technology and Automation in Swedish Agriculture: A Pilot Study. *J. Agromedicine* **2018**, *23*, 215–226. [[CrossRef](#)]
55. Perez, J.F.; Traversini, V.; Fioriti, M.; Taddei, G.; Montalti, M.; Tommasi, E. Shift and Night Work Management in European Companies. *Qual. Access Success* **2019**, *20*, 157–165.
56. Pallesen, S.; Bjorvatn, B.; Magerøy, N.; Saksvik, I.B.; Waage, S.; Moen, B.E. Measures to Counteract the Negative Effects of Night Work. *Scand. J. Work. Environ. Health* **2010**, *36*, 109–120. [[CrossRef](#)]
57. Schernhammer, E.; Kroenke, C.; Laden, F.; Hankinson, S. Night Work and Risk of Breast Cancer. *Epidemiology* **2006**, *17*, 108–111. [[CrossRef](#)]
58. Eurostat. *Employed Persons Working at Nights as a Percentage of the Total Employment, by Sex, Age and Professional Status (%) [Dataset]*; Eurostat: Luxembourg, 2021.