

The balance between safety and productivity and its relationship with human factors and safety awareness and communication in aircraft manufacturing

Author(s)

Karanikas, Nektarios; Melis, Damien Jose; Kourousis, Kyriakos

DOI

[10.1016/j.shaw.2017.09.001](https://doi.org/10.1016/j.shaw.2017.09.001)

Publication date

2018

Document Version

Proof

Published in

Safety and Health at Work

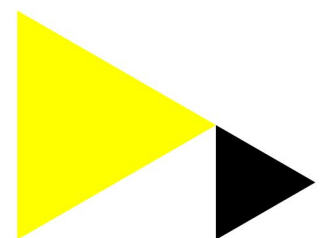
License

CC BY-NC-ND

[Link to publication](#)

Citation for published version (APA):

Karanikas, N., Melis, D. J., & Kourousis, K. (2018). The balance between safety and productivity and its relationship with human factors and safety awareness and communication in aircraft manufacturing. *Safety and Health at Work*, 9(3), 257-264. <https://doi.org/10.1016/j.shaw.2017.09.001>

**General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please contact the library: <https://www.amsterdamuas.com/library/contact/questions>, or send a letter to: University Library (Library of the University of Amsterdam and Amsterdam University of Applied Sciences), Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

Amsterdam University of Applied Sciences

The balance between safety and productivity and its relationship with human factors and safety awareness and communication in aircraft manufacturing

Karanikas, N.; Melis, Damien Jose; Kourousis, Kyriakos

Published in:
Safety and Health at Work

DOI:
[10.1016/j.shaw.2017.09.001](https://doi.org/10.1016/j.shaw.2017.09.001)

[Link to publication](#)

Citation for published version (APA):
Karanikas, N., Melis, D. J., & Kourousis, K. (2017). The balance between safety and productivity and its relationship with human factors and safety awareness and communication in aircraft manufacturing. *Safety and Health at Work*. DOI: 10.1016/j.shaw.2017.09.001

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

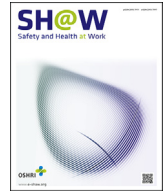
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please contact the library: <http://www.hva.nl/bibliotheek/contact/contactformulier/contact.html>, or send a letter to: University Library (Library of the University of Amsterdam and Amsterdam University of Applied Sciences), Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.



Contents lists available at [ScienceDirect](#)

Safety and Health at Work

journal homepage: www.e-shaw.org



Original Article

The Balance Between Safety and Productivity and its Relationship with Human Factors and Safety Awareness and Communication in Aircraft Manufacturing

Nektarios Karanikas^{1,*}, Damien Jose Melis², Kyriakos I. Kourousis^{2,3}

¹Aviation Academy, Faculty of Technology, Amsterdam University of Applied Sciences, Amsterdam, Netherlands

²School of Engineering, RMIT University, Melbourne, Victoria, Australia

³School of Engineering, University of Limerick, Limerick, Ireland

ARTICLE INFO

Article history:

Received 21 June 2017

Received in revised form

19 August 2017

Accepted 6 September 2017

Available online xxx

Keywords:

aircraft manufacturing

human factors

productivity and safety

safety

safety communication

ABSTRACT

Background: This paper presents the findings of a pilot research survey which assessed the degree of balance between safety and productivity, and its relationship with awareness and communication of human factors and safety rules in the aircraft manufacturing environment.

Methods: The study was carried out at two Australian aircraft manufacturing facilities where a Likert-scale questionnaire was administered to a representative sample. The research instrument included topics relevant to the safety and human factors training provided to the target workforce. The answers were processed in overall, and against demographic characteristics of the sample population.

Results: The workers were sufficiently aware of how human factors and safety rules influence their performance and acknowledged that supervisors had adequately communicated such topics. Safety and productivity seemed equally balanced across the sample. A preference for the former over the latter was associated with a higher awareness about human factors and safety rules, but not linked with safety communication. The size of the facility and the length and type of employment were occasionally correlated with responses to some communication and human factors topics and the equilibrium between productivity and safety.

Conclusion: Although human factors training had been provided and sufficient bidirectional communication was present across the sample, it seems that quality and complexity factors might have influenced the effects of those safety related practices on the safety–productivity balance for specific parts of the population studied. Customization of safety training and communication to specific characteristics of employees may be necessary to achieve the desired outcomes.

© 2017 Occupational Safety and Health Research Institute, Published by Elsevier Korea LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Aircraft manufacturing has been experiencing continuous growth over the past 10 years due to the increasing need for new aircraft. This expansion introduces challenges with regard to the effective management of the human factors involved in the manufacturing process. Education is essential for the development of positive attitudes of workers towards safety, especially when training is followed by active engagement of the workforce in organizational decision making for the development of safety rules e.g., [1,2]. To ensure that management and end-users share similar safety attitudes and safety infractions on the work floor are

prevented, training must integrate the perspectives of both managers and workers, and an effective safety communication across various organizational levels is necessary [3–5].

In general, when workers are satisfied with the working conditions and feel safe from injuries, they become more productive [6,7]. However, theoretical knowledge about human factors and boundaries of human performance is not always transformed into daily practice to the extent that is expected by management through compliance with safety standards and rules, and learning from past errors is not always visible e.g., [8,9]. Although training may be offered, safety skills are frequently obtained through practice. The experience obtained from own tasks and transferred

* Corresponding author. Postbus 1025/1000 BA, Amsterdam, Netherlands.
E-mail address: nektkar@gmail.com (N. Karanikas).

by skilled coworkers to less experienced staff is the driving force for the development of positive attitudes towards safety [8,10,11]. Thus, while experienced staff might have accumulated relevant knowledge based on practice and training, junior staff tend to develop their skills related to human performance management and safety rules' observance over time. Also, the position that workers hold within a company influences their attitudes regarding their active involvement in safety practices [12,13] to a greater extent than the knowledge gained from previous jobs in other facilities [11,14].

The differences mentioned above regarding safety perceptions amongst various levels of job experience reflect the variety of workers' practices when they cope with competing goals during their tasks. The continuous trade-offs between efficiency and thoroughness are inevitable in a working environment, where staff are required to perform their activities by simultaneously meeting multiple and occasionally contradictory objectives (e.g., productivity, quality, safety, security) [15,16] and employees are subject to dilemmas and ambiguity during decision-making [17]. As Dekker [18] pointed out, inadequate or inappropriate resources, such as time, knowledge, and tools, affect individual and organizational performance and contribute to the migration of companies into hazardous states and, possibly, unwanted outcomes (e.g., safety events and lower quality of deliverables). However, a competitive relationship between safety and production is not the only option if managers consider the dependency between these two objectives and perceive the necessity to establish an equilibrium [19,20].

Apart from organizational factors that affect business performance, individual performance of manufacturing workers is influenced by various factors in the working environment, such as motivation, communication, ergonomics and automation e.g., [21,22]. Communication is of particular importance because of its critical role in ensuring safety; a proper understanding of human factors principles and safety practices can only stem from effective communication. Especially, team communication enhances awareness of hazards and the implications of safety infringements, which might lead to losses [16,23,24]. Supervisors and managers who actively communicate their opinions and requirements to the workers must be aware of the potential conflicts between production and safety goals, and senior staff must understand that their attitudes affect the perceptions of the workforce. A lack of such bidirectional communication avenues may cause increased task demands and lower clarity of the work objectives and priorities, both of which are associated with unsafe behaviors and an inconvenient working environment [25].

Moreover, the proper management of ergonomics has been linked to accident and incident prevention for decades. Earlier studies like Resnick and Zanotti [26] and Kadefors et al. [27] noted that a comfortable environment supported operators in performing their job tasks productively, and a safe working environment increased the confidence of personnel, reducing, in turn, the occurrence of injuries. Providing employees with well-designed workstations and training in proper body postures allows them to work more efficiently. In this regard, several studies have associated poor ergonomics with lower productivity [25,28,29]. Also, the combination of tedious tasks with long working periods is likely to affect individual performance negatively [30] and lead to injuries [31]. Improved ergonomics in general not only prevents injuries, but also positively influences productivity [32,33].

Various researchers have widely shared relevant knowledge and research on the effects of the factors mentioned above on perceptions and performance of employees and organizations, e.g., [34,35]. However, to the best knowledge of the authors, there has been little research regarding the extent to which awareness of the influence of human factors and safety rules on task performance

affect the balance between safety and productivity within a manufacturing environment. Such research would indicate the effects of human factors and safety awareness and communication on the realization of the dynamic business objectives of safety and productivity and support organizations in improving their corresponding programs. In order to fill this gap in the literature, we conducted a questionnaire-based pilot survey with the aim to test the following hypotheses:

- Hypothesis 1: The more the awareness about human factors and safety, the more the favor of safety over productivity;
- Hypothesis 2: The more the human factors and safety communication, the more the favor of safety over productivity.

2. Materials and methods

2.1. Survey tool

Past studies researching the links between safety and productivity have employed two primary methods of data collection: the use of available data sets e.g., [8,23] and data collection through surveys e.g., [10,24]. Although interviews can provide detailed information, time constraints and availability of participants can affect their efficiency e.g., [36]. Thus, for this pilot research, a questionnaire survey was preferred. In order to test the hypotheses, a questionnaire was used to capture the perceptions of participants across the following three research questions (RQs):

- RQ1: To what extent do employees favor safety over productivity?
- RQ2: To what extent are employees aware of the effects of safety rules and human factors on their tasks?
- RQ3: How sufficiently do managers and supervisors communicate with employees regarding human factors and safety?

The questionnaire included a mixture of questions presented in a random order to each participant as a means to minimize respondents' bias, and was divided into sections with a total of 34 questions. The first section consisted of four questions gathering information about the participants' profile; these were used as independent variables in the statistical tests, as a means to search for differences in responses across companies, level of experience, type of employment, and weekly working hours. Table 1 presents an adapted form of the instrument with the remaining (30) questions grouped by RQ.

Each of the individual questions addressed topics on:

- Awareness of human factors and safety rules, and communication of those across the company (HF1 to HF18);
- The balance between safety and productivity (SP1 to SP12).

The topics included in the questions were selected on the basis of the literature reviewed and in conjunction with the main human factors topics discussed in respective books, especially ones addressed to aviation, engineering, and manufacturing [37–40]. The aim was to include various human factors themes to meet the pilot research objectives via responses to indicative human factors topics, without overwhelming the participants with a large number of questions. It is noted that although various instruments have been introduced in the literature for measuring human factors and safety awareness and communication e.g., [24,29,41,42], those cover a vast variety of relevant topics which could be unknown or incomprehensible to the research participants.

Table 1

Research questionnaire adapted version, where grouped questions are shown

Question code	Question	Direction of question (positive +, negative -)
Section 1		
D1	Where do you work?	Not applicable
D2	How many years have you been working in this company?	Not applicable
D3	Which best describes your employment status?	Not applicable
D4	How many hours per week do you usually work?	Not applicable
Section 2		
RQ1: To what extent do employees favor safety over productivity?		
SP1	Occasional breach of workplace safety rules is needed to meet work demand	-
SP2	Lack of appropriate work tools will lead to task stoppage and inquiring for proper tools at the expense of task duration	+
SP3	Lack of complete knowledge in using a particular machine/tool will slow down working pace	+
SP4	Asking colleagues for help is required when skills to operate a machine or tool are missing, although this will prolong accomplishment of tasks	+
SP5	Demands for faster delivery of aircraft parts will decrease focus on the process	+
SP6	Observation of all safety rules will cause late delivery of tasks	-
SP7	Spending more time on a single task due to safety concerns is negative, because it will prevent completion of the work package in time	-
SP8	Use of appropriate safety clothes/gear might slow down working pace	+
Section 3		
RQ2: To what extent are employees aware of the effects of safety rules and human factors on their tasks?		
HF1	Performance of work tasks in the presence of distractions will lead to errors	+
HF2	Learning from mistakes that lead to poor quality of work is part of performance improvement	+
HF3	It is better to pay more attention to work than surroundings inside the workshop (equipment, tools, other people, etc.)	-
HF4	Commission of workplace rule infraction is usually conscious	+
HF5	Repetitive tasks cause less focus on the process	+
HF6	Work errors are caused only when people interact with other parts of their working environment	-
HF7	Wrong positioning of hands, arms, or body during a job prevents it from being done properly	+
HF8	Ability to spot when others infringe safety rules is important	+
HF9	Work pressure leads to unpredictable errors	-
HF10	Understanding why rules must be followed when performing tasks is important	+
HF16	Working at a convenient pace prevents injuries caused by equipment and machinery	+
HF17	Numerous steps for completing a task will inevitably jeopardize exercise of safety rules	-
HF18	Few doubts about how to use a machine must not lead to stoppage of task performance	-
Section 4		
RQ3: How sufficiently do managers and supervisors communicate with employees regarding human factors and safety?		
HF11	Management of my company provides workers with enough information to make us aware of human error problems at the workplace	+
HF12	The supervisors of my company regularly talk to employees about work safety practices and rules	+
HF13	The supervisors of my company talk to workers about safety aspects of newly introduced tasks	+
HF14	Supervisors of my company pass safety concerns of employees to management	+
HF15	Management of my company sometimes does not make practical rules about safety, because managers have a limited understanding of the processes that workers use to perform tasks	-
SP9	At my company, employees communicate their difficulties in meeting production deadlines to supervisors	+
SP10	At my company, workers communicate the cases of errors that require repetition of tasks from the beginning to supervisors	+
SP11	Discussion with supervisors about work related issues is sometimes avoided, because it will lead to late accomplishment of tasks	-
SP12	The safety rules of my company are adequately discussed with all employees before the start of tasks, so time is not spent on access to such information at the expense of timely completion of tasks	+

A preliminary version of the questionnaire was developed and administered to 10 tertiary education engineering students who provided feedback on the clarity of the questions, which led to its respective amendment. In order to achieve relevance of the questions with the background and expected knowledge level of the respondents, the safety personnel of the organizations involved in this study commented further on the questionnaire and confirmed that its final version referred to the most important

and relevant topics covered in their organizations' human factors and safety training. In addition, the same persons verified that the questions did not raise ethical issues. The themes of the questionnaire included: knowledge about human factors and safety practices; improvement through learning; distraction and attention when performing tasks; effects of the working environment and respective interactions; nature and demands of tasks; body postures; communication; attitude towards safety rules; use of

personal protective equipment; and efficiency-thoroughness trade-offs.

A four-point Likert scale was utilized to ensure that respondents provided either “positive” or “negative” answers since “neutral” responses would likely have no merit for attitudinal grading [43]. Each question was worded either “positively” or “negatively” to avoid a respondent fatigue effect. An attitude score was assigned to each of the Likert responses “Strongly Disagree”, “Disagree”, “Agree”, and “Strongly Agree” with a 1–4 score given from the most “negative” to the most “positive” response. Especially for RQ1, the corresponding questions were formulated in a way that the higher the score in the Likert scale, the more was the favor for safety over productivity.

2.2. Sample

The paper-based questionnaire was administered to workers of two Australian facilities (Plant A and Plant B) which manufacture aircraft components and assemblies. The aircraft manufacturing organizations were selected based on the criteria of proximity to the researchers and different size; Plant A is owned by a foreign aircraft manufacturing group, whereas Plant B is a facility that provides Plant A with aircraft parts. The target population was workers at the production floor for aircraft parts. Out of the target population of Plant A (i.e., 56 workers) and Plant B (i.e., 15 workers), 29 employees from Plant A (i.e., about 52%) and eight employees from Plant B (i.e., about 55%) participated in the pilot survey. The sample was considered as adequate since previous studies have been performed on 45–60% of the target populations e.g., [10,24,30,44]. The demographic data obtained from the first four questions are shown in Table 2.

In order to avoid identification of the participants and minimize the effects of social desirability [45,46], the questionnaire was anonymous, and one of the researchers administered it to all employees of the target population over a period of 1 week. The participation in the survey was voluntary, and the workers were prompted to drop the filled questionnaire in a secure dedicated box within 10 days. The box from each of the facilities was collected from the researchers, and no other person had access to its contents.

2.3. Analysis methods

The data were analyzed with the use of the SPSS version 22 software package (IBM, IBM SPSS Statistics for Windows, VERSION 22.0. Armonk, NY, USA, 2013) [47]. The scores given to the negatively formulated questions were mirrored to achieve the same direction of all questions and perform valid comparisons (e.g., Score 3 in negative questions was transformed to Score 2). Since a 4-point Likert scale was used, nonparametric statistics were used with median value calculations. The significance level for all statistical tests was set to 0.05.

Table 2
Research sample

Variable	Independent variable	Sample (%)	Plant A (%)	Plant B (%)
Plant	Plant A	78.4	-	
	Plant B	21.6		
Year of employment in the company	≤5	64.9	62.0	75.0
	6–10	29.7	31.0	25.0
	≥11	5.4	7.0	0
Employment status	Full-time	89.2	86.3	100.0
	Apprentice	10.8	13.7	0
Working h/wk	31–40	48.6	41.4	75.0
	41–50	51.4	58.6	25.0

In order to search for significant differences with regard to the independent variables across the RQ1, RQ2, and RQ3 groups of questions, the medians of the respective sets of questions per participant were considered (e.g., RQ1 score for a specific respondent was calculated as the median of the answers to the questions SP1 to SP8). Apart from the research questions, potential differences were also explored for each question against the independent variables. Mann-Whitney tests were used to investigate the effects of independent variables with two conditions (i.e., plant, employment type, and working hours per week) and Kruskal-Wallis tests were conducted for the employment length variable, which had three conditions. Due to the relatively small sample of this pilot study, the exact significance values of the SPSS results were considered.

Spearman's bivariate and partial correlations were performed as a means to explore possible relationships of RQ1 (i.e., safety and productivity balance) with RQ2 (i.e., awareness about human factors and safety rules) and/or RQ3 (i.e., safety communication between supervisors/managers and technicians). Cronbach α for the responses per research question ranged between 0.672 and 0.718, meaning that the instrument used was sufficiently reliable. Hence, there was an adequate consistency across all questions and the overall results are deemed as valid.

3. Results

The results per question for the whole sample are presented in Table 3, grouped by RQ and sorted by question code in order to facilitate the presentation of the findings.

The Mann-Whitney and Kruskal-Wallis tests revealed that the independent variables were not associated with the responses to the research questions RQ1, RQ2, and RQ3. Regarding the significant differences across individual questions (Table 4), the results suggested that the communication of human factors and safety about regular and new tasks (questions HF12 and HF13), the reporting of workers' concerns by supervisors to management (question HF14), and the managers' understanding of the nature and complexity of the activities during the development of safety rules (question HF15) were evaluated more positively by Plant B workers than the Plant A workers. However, the latter appeared to be more eager than Plant B workers to reduce their productivity when proper equipment was not available (question SP2). Also, the findings showed that the higher the employment length, the greater the awareness of end-users of how their performance is affected by their interaction with factors at the local working environment (question HF6), and workers under full employment status claimed that they were not concerned about losing their focus during repetitive jobs (question HF5).

Regarding the relationship of RQ3 with RQ1 and RQ2, when considering the whole sample, Spearman's bivariate correlations showed that there was a positive monotonic relationship between RQ1 and RQ2 ($n = 37$, Spearman's correlation coefficient, $\rho = 0.502$, $p = 0.002$), whereas no association between RQ1 and RQ3 was found. When considering the effects of the independent variables, the relationship between RQ1 and RQ2 was statistically significant for Plant A ($n = 29$, $\rho = 0.548$, $p = 0.002$), the lowest length of employment at the companies (i.e., 0–5 years), ($n = 24$, $\rho = 0.473$, $p = 0.000$), and full-time employees ($n = 33$, $\rho = 0.533$, $p = 0.001$). Only for staff under longer employment (i.e., 6 years and more) the relationship between RQ1 and RQ3 was statistically significant with a negative direction ($n = 11$, $\rho = -0.682$, $p = 0.021$). Partial correlations showed that when controlling for communication (i.e., RQ3), there was still a positive significant association of safety and human factors knowledge (i.e., RQ2) with the safety over productivity balance (i.e., RQ1), ($n = 34$, $\rho = 0.626$, $p = 0.000$). No statistical

Table 3
Median values per question

Question code	Question	Median*
RQ1: To what extent do employees favor safety over productivity?		
SP1	Occasional breach of workplace safety rules is needed to meet work demand	2
SP2	Lack of appropriate work tools will lead to task stoppage and inquiring for proper tools at the expense of task duration	4
SP3	Lack of complete knowledge in using a particular machine/tool will slow down working pace	3
SP4	Asking colleagues for help is required when skills to operate a machine or tool are missing, although this will prolong accomplishment of tasks	3
SP5	Demands for faster delivery of aircraft parts will decrease focus on the process	3
SP6	Observation of all safety rules will cause late delivery of tasks	2
SP7	Spending more time on a single task due to safety concerns is negative, because it will prevent completion of the work package in time	2
SP8	Use of appropriate safety clothes/gear might slow down working pace	2
RQ2: To what extent are employees aware of the effects of safety rules and human factors on their tasks?		
HF1	Performance of work tasks in the presence of distractions will lead to errors	3
HF2	Learning from mistakes that lead to poor quality of work is part of performance improvement	3
HF3	It is better to pay more attention to work than surroundings inside the workshop (equipment, tools, other people, etc.)	3
HF4	Commission of workplace rule infraction is usually conscious	3
HF5	Repetitive tasks cause less focus on the process	2
HF6	Work errors are caused only when people interact with other parts of their working environment	3
HF7	Wrong positioning of hands, arms, or body during a job prevents it from being done properly	3
HF8	Ability to spot when others infringe safety rules is important	3
HF9	Work pressure leads to unpredictable errors	3
HF10	Understanding why rules must be followed when performing tasks is important	3
HF16	Working at a convenient pace prevents injuries caused by equipment and machinery	3
HF17	Numerous steps for completing a task will inevitably jeopardize exercise of safety rules	2
HF18	Few doubts about how to use a machine must not lead to stoppage of task performance	2
RQ3: How sufficiently do managers and supervisors communicate with employees regarding human factors and safety?		
HF11	Management of my company provides workers with enough information to make us aware of human error problems at the workplace	2
HF12	The supervisors of my company regularly talk to workers about work safety practices and rules	2
HF13	The supervisors of my company talk to workers about safety aspects of newly introduced tasks	2
HF14	Supervisors of my company pass safety concerns of employees to management	3
HF15	Management of my company sometimes does not make practical rules about safety, because managers have a limited understanding of the processes that staff use to perform tasks	3
SP9	At my company, workers communicate their difficulties in meeting production deadlines to supervisors	3
SP10	At my company, workers communicate the cases of errors that require repetition of tasks from the beginning to supervisors	3
SP11	Discussion with supervisors about work related issues is sometimes avoided, because it will lead to late accomplishment of tasks	2
SP12	The safety rules of my company are adequately discussed with all workers before the start of tasks, so time is not spent on access to such information at the expense of timely completion of tasks	2

* After mirroring responses to negatively formulated questions.

relationship was detected between RQ3 and RQ1 when controlling for RQ2.

4. Discussion

A qualitative evaluation of the responses to the individual questions related to the research questions RQ2 and RQ3 indicates that workers were aware of the role of human factors and safety rules in their job performance and there was adequate communication between management and workers around those topics. Therefore, the respective training had produced the desired output, and safety communication had been established, as suggested in the literature and expected by the management of the organizations. Regarding the first research question (RQ1), the range of the scores of the individual questions shows that safety did not always appear as a top priority and the workers showed a tendency to balance it with production requirements. This implies that

employees self-organized their safety obligations during their day-to-day activities, thus being able to apply safety rules that best suit the situations. This particular finding confirms the literature discussing the unavoidable trade-offs between efficiency and thoroughness e.g. [15,16], which in this research regarded the relationship between manufacturing production and safety. Moreover, the findings suggest that an equilibrium between safety and production was feasible, as claimed by Kramer [19] and Dekker [20].

The independent variables (i.e., demographic characteristics) did not affect the overall responses to the questions RQ1, RQ2, and RQ3, hence suggesting common perceptions amongst workers regardless of the company, employment length and status, and weekly working hours. However, when considering the results of individual questions, a few differences were observed. The apprentices believed, to a greater extent than the full-time workers, that repetitive tasks decreased their focus on the job. Although the

Table 4
Mean ranks of responses to questions with significant differences

Question code	Statistical significance (<i>p</i>)	Mean ranks		
		Plant A	Plant B	
HF12	0.006	16.62	27.63	
HF13	0.030	17.02	26.19	
HF14	0.001	16.22	29.06	
HF15	0.019	16.50	25.50	
SP2	0.003	21.36	10.44	
Employment length (y)				
		≤ 5	6–10	≥ 11
HF6	0.040	17.67	18.91	35.50
Employment type				
		Full-time	Apprentice	
HF5	0.042	17.91	28.00	

authors did not identify any relevant published research, the aforementioned differences may be attributed to the different levels of experience and human factors awareness between full-time employees and apprentices. On the one hand, the latter are at the beginning of their careers and their awareness about human factors effects on their performance is expected to be high following their introductory training; on the other hand, experienced workers can gradually become confident about their performance during repetitive tasks.

The longer employees worked for the same company, the more they realized that errors were caused by people interacting with their local working environment (e.g., equipment, tools, coworkers) and that unsafe actions and decisions were not merely a result of their own performance. This suggests that as working experience under the same conditions increases, the awareness of how local factors affect human performance becomes more profound. Relevant literature was not identified; thus, the authors could not assess whether this finding confirms past research or not.

The size of the aircraft manufacturing company affected some aspects of communication across organizational levels; Plant B workers rated higher four relevant questions than Plant A workers. Although additional explanatory research would be required to obtain insights into the underlying reasons, the authors believe that this finding can be attributed to the lower complexity of the small company due to fewer employees and limited scope of operations. The smaller the firm, the less the distance amongst workers, supervisors, and managers, thus allowing an increased understanding of the role of human factors and safety in daily activities and higher levels of workers' engagement in the development of safety rules. This study was performed only in two companies and the findings about differences regarding communication cannot be seen as conclusive. Nevertheless, the results are aligned with previous research which showed a similar effect of the company size on internal communication and the investment of more time in oral communication in small firms than in large enterprises [4,48,49].

Although Plant B workers rated some communication aspects higher than Plant A workers, the latter seemed less keen than the former on jeopardizing safety when they did not have access to proper tools to accomplish their tasks. The authors did not find literature discussing variations of such safety behaviors across different company sizes. Some older and more recent studies in the construction industry refer only to the relationship between size of the firms and safety performance [50–53]. Therefore, further research on this topic is necessary.

Regarding hypothesis 1, the results suggested that increased awareness of human factors topics and safety rules was associated

with the workers' preference of safety over productivity. This confirms the literature referring to the positive effects of human factors and safety training on minimizing adverse outcomes that source from production pressures in the working environment. Although this association did not differ between the two groups of weekly working hours, the influence of human factors awareness on the inclination towards safety was significant only for Plant A workers, workers with a few years' employment, and full-time workers. Due to the lack of relevant research and the pilot nature of this study, the authors were not able to identify concrete justifications about these findings and more research is needed. However, as an attempt to offer a preliminary explanation based merely on the perspective of the researchers, it seems that variations of production demands might be a common characteristic of the particular groups of workers. Since Plant A is more complex than Plant B in terms of size and activities, one may assume that production demands in Plant A varied over time more than in Plant B, a factor that in turn affected the responses of the workers to the corresponding questions. Similarly, the exposure of full-time employees and staff under longer employment to higher variations of production demands compared to apprentices, who in practice perform predefined work packages, might explain the specific finding.

Contradictory to the expectations raised by the literature, the level of communication between managers and workers did not influence the way the former acted on balancing safety and productivity, hence hypothesis 2 was not confirmed. Surprisingly, the results for employees under longer employment suggested that the more the communication between workers and management about human factors and safety rules, the higher the favor of productivity over safety. The researchers contemplate that the specific finding implies problems in the quality of communication or/and the presence of factors related to the interpersonal relations between managers and experienced workers. Nevertheless, further research is considered necessary to explain the specific finding. Additionally, the results from partial correlations confirmed that, in the specific companies, knowledge had a stronger effect on the favor of safety over productivity compared to communication. Overall, the findings above suggest that human factors and safety communication alone did not affect the equilibrium between safety and productivity, this possibly reflecting issues related to the quality of communication along with cultural aspects within the organizations, the investigation of which was out of the scope of this research.

5. Conclusion

The workers at both aircraft manufacturing companies, which differed in terms of size and operations, demonstrated a similar level of awareness about human factors and safety rules, and they equally balanced production and safety regardless of the facility, employment length and type, and weekly working hours. Participants across the whole sample recognized the presence of sufficient communication between them and their supervisors and managers. The length and type of employment influenced some attitudes towards the effects of human factors on task performance, and staff of the small organization occasionally reported a more frequent safety communication compared to the large organization. Awareness about human factors topics was associated with a preference of safety over production for staff of the larger aircraft manufacturing facility, under shorter employment and full-time contract. Such a relationship was not identified when considering adequacy of communication between workers and managers/supervisors and it was even found to be negative for long-employed workers.

Hence, although human factors training had been provided and sufficient bidirectional communication was present across the sample, it seems that quality and complexity factors might have influenced the effects of those safety-related practices on specific parts of the population studied. Therefore, tailoring safety training and communication to specific characteristics of employees may be necessary to address this issue. Customization is expected to require more resources; hence its realization depends on the capability, objectives and vision of each organization.

This pilot study explored the attitudes of staff from a single geographical region and industry sector regarding human factors and safety rules and the relationship between productivity and safety, and partially confirmed the suggestions of the relevant literature. Although the small and unbalanced sample used in this research does not allow to claim generalization and conclusiveness of the findings, the current study demonstrated the need for further research about the efficiency-thoroughness trade-off either separately or in conjunction with the perceptions of staff on human factors, safety rules, and communication. Thus, future work is recommended across other aircraft manufacturing companies and regions in order to investigate the need to modify respective safety initiatives. Also, additional research is suggested regarding the following findings of this study that could not be evaluated against the literature reviewed: the perception of effects of monotonous tasks on job performance across full-time and part-time workers, the relationship between length of employment and recognition of effects of working environment on task performance, the impact of company size on specific safety behaviors, the influence of human factors awareness on the safety-productivity equilibrium under varying production demands, and the association of the effectiveness of communication between management and staff with employment duration.

The methodology employed in this pilot study enabled an integrated approach through the use of a questionnaire which covered a broad spectrum of human factors and safety topics, appropriately tailored to the human factors and safety training provided by the organizations studied. Although social desirability of the participants might have affected the responses, the questionnaire used in this research is based on a theoretical framework and was proved sufficiently reliable. Nevertheless, the authors suggest a customization of similar questionnaires to the needs of any organization that plans to perform similar investigations, and the validation and explanation of the results through interviews, observations, or other suitable methods.

Conflicts of interest

All authors have no conflicts of interest to declare.

References

- [1] Bunn WB, Pikelný DB, Slavin TJ, Paralkar S. Health, safety, and productivity in a manufacturing environment. *J Occup Environ Med* 2001;43:47–55.
- [2] Maudgalya T, Genaidy A, Shell R. Productivity quality costs safety: a sustained approach to competitive advantage - a systematic review of the national safety council's case studies in safety and productivity. *Hum Factors Ergon Manuf* 2008;18:152–79.
- [3] Geldart S, Lohfeld L, Shannon HS, Smith CA. Organizational practices and workplace health and safety: A cross-sectional studying manufacturing companies. *Saf Sci* 2010;48:562–9.
- [4] Hola J. Internal communication in the small and medium sized enterprises. *E&M Ekon Manage* 2012;15:32–45.
- [5] Hall A, Oudyk J, King A, Naqvi S, Lewchuk W. Identifying knowledge activism in worker health and safety representation: A cluster analysis. *Am J Ind Med* 2016;59:42–56.
- [6] Luria G, Yagil D. Safety perception referents of permanent and temporary employees: safety climate boundaries in the industrial workplace. *Accid Anal Prev* 2010;42:1423–30.
- [7] Dode P, Greig M, Zolfaghari S, Neumann WP. Integrating human factors into discrete event simulation: a proactive approach to simultaneously design for system performance and employees' well being. *Int J Prod Res* 2016;54:3105–17.
- [8] Griffin MA, Neal A. Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. *J Occup Health Psychol* 2000;5:347–58.
- [9] Bahari SF. An investigation of safety training and safety outcome in a manufacturing plant. *J Teknol* 2013;64:59–65.
- [10] Cheyne C, Oliver A, Tomas JM, Cox S. The architecture of employee attitudes to safety in the manufacturing sector. *Personnel Rev* 2002;31:649–70.
- [11] Nesheim T, Gressgård LJ. Knowledge sharing in a complex organization: Antecedents and safety effects. *Saf Sci* 2014;62:28–36.
- [12] Ahasan A. Human adaptation to shift work in improving health, safety and productivity - some recommendations. *Work Study* 2002;51:9–16.
- [13] Denkowski MR, Kelly BG, Garvin M. A paradigm shift in well control training and assessment. In IADC/SPE Drilling Conference and Exhibition 1–3 March 2016, Fort Worth (TX). Society of Petroleum Engineers, 2016.
- [14] Håvold JI. Safety-culture in a Norwegian shipping company. *J Saf Res* 2005;36:441–58.
- [15] Hollnagel E. *The ETTO principle: efficiency-thoroughness trade off*. Farnham (UK): Ashgate; 2009.
- [16] Fritzsche L, Wegge J, Schmauder M, Kliegel M, Schmidt KH. Good ergonomics and team diversity reduce absenteeism and errors in car manufacturing. *Ergonomics* 2014;57:148–61.
- [17] Nathanael D, Tsagkas V, Marmaras N. Trade-offs among factors shaping operators decision-making: the case of aircraft maintenance technicians. *Cogn Technol Work* 2016;18:807–20.
- [18] Dekker S. Drift into failure: from hunting broken components to understanding complex systems. Farnham (UK): Ashgate; 2011.
- [19] Kramer W. The battle between production & safety: safety in the modern do-more-with-less economy. *Prof Saf* 2013;14–15.
- [20] Dekker S. Production and safety. *Hindsight* 2013;17:8–9.
- [21] Narayan V. Business performance and maintenance - How are safety, quality, reliability, productivity and maintenance related? *J Qual Maint Eng* 2012;18:183–95.
- [22] Li WC, Greaves M, Durando D, Lin JJ. The activated failures of human-automation interactions on the flight deck. *J Aeronaut Astronaut Aviation* 2016;48:163–71.
- [23] Kaminski M. Unintended consequences: organizational practices and their impact on workplace safety and productivity. *J Occup Health Psychol* 2001;6:127–38.
- [24] Goncalves R, Lancmana S, Trudeb L, Jarbimb TA, Sznclwarz LI, Santosa MC, Freeman A. An ergonomic approach to reorganize parking inspection agents' work productivity, health and safety in Sao Paulo, Brazil. *Work* 2010;36:345–53.
- [25] Clarke S. Safety climate in an automobile manufacturing plant: The effects of work environment, job communication and safety attitudes on accidents and unsafe behaviour. *Personnel Rev* 2006;35:413–30.
- [26] Resnick M, Zanotti A. Using ergonomics to target productivity improvements. *J Comput Ind Eng* 1997;33:185–8.
- [27] Kadefors R, Engstrom T, Petzil J, Sundstrom L. Ergonomics in parallelized car assembly: a case study, with reference also to productivity aspects. *Appl Ergon* 1996;27:101–10.
- [28] Shikda AA, Sawaqed NM. Worker productivity, and occupational health and safety issues in selected industries. *J Comput Ind Eng* 2003;45:563–72.
- [29] Dianat I, Vahedi A, Dehnavi S. Association between objective and subjective assessments of environmental ergonomic factors in manufacturing plants. *Int J Ind Ergon* 2016;54:26–31.
- [30] Allan HM, Bunn WB, Slavin TJ. Do long work hours impact health, safety, and productivity at a heavy manufacturer? *J Occup Environ Med* 2007;26:148–71.
- [31] Salminen S. Long working hours and shift work as risk factors for occupational injury. *Ergon Open J* 2016;9:15–26.
- [32] Govindaraju M, Pennathur A, Mital A. Quality improvement in manufacturing through human performance enhancement. *J Integr Manuf Syst* 2001;10:360–7.
- [33] Sobhani A, Wahab MM, Neumann WP. An innovative modeling method to evaluate Human factor effects on the performance of manufacturing systems. In: *Industrial Engineering and Engineering Management (IEEM)*, IEEE Int 2016. p. 130–4.
- [34] Salas E, Maurino D. *Human factors in aviation*. 2nd ed. Oxford (UK): Elsevier; 2010.
- [35] Dhillon BS, Liu Y. Human error in maintenance: A review. *J Qual Maint Eng* 2006;21:21–36.
- [36] Kumar R. Chapter 9: Selecting a method for data collection. In: *Research methodology*. 2nd ed. London (UK): SAGE Publications Ltd; 2005. p. 117–43.
- [37] Sandom C, Harvey RS. *Human factors for engineers*. London (UK): The Institution of Engineering & Technology; 2004.
- [38] Lehto MR, Buck JR. *Introduction to human factors and ergonomics for engineers*. New York (NY): Lawrence Erlbaum Associates; 2008.
- [39] Federal Aviation Administration (FAA). *Human factors. In aviation maintenance technician handbook 8083-30* (p. 14–1 to 14-30). Washington (DC): Federal Aviation Administration, 2008.
- [40] Garland DJ, Wise JA, Hopkin VD. *Handbook of aviation human factors*. 2nd ed. Boca Raton (FL): CRC Press, Taylor & Francis Group; 2010.
- [41] Meister D. *Human factors testing and evaluation*, vol. 5. Amsterdam: Elsevier Science Publishers; 1986.

- [42] Hobbs A, O'Hara J, Adelstein B, Null C. Defining reliability and robustness from a human factors perspective. In: *Space safety is no accident*. Cham, Switzerland: Springer International Publishing; 2015. p. 277–83.
- [43] Kumar R. Chapter 10: Collecting data using attitude scales. In: *Research methodology*. 3rd ed. London (UK): SAGE Publications Ltd; 2011. p. 167–76.
- [44] Kumar R. Chapter 12: Selecting a sample. In: *Research methodology*. 3rd ed. London (UK): SAGE Publications Ltd; 2011. p. 191–214.
- [45] Derek LP, Kevin JC. Some effects of "social desirability" in survey studies. *Am J Sociol* 1972;77:921–40.
- [46] DeMaio TJ. Social desirability and survey measurement: A review. In: *Surveying subjective phenomena*, vol. 2. New York (NY): Russell Sage Foundation; 1984. p. 257–81.
- [47] IBM. IBM SPSS Statistics for Windows, Version 22.0. NY: Armonk; 2013.
- [48] Roebuck DB, Sigtler KW, Brush CC. Organizational size, company type, and position effects on the perceived importance of oral and written communication skills. *J Manage Issues* 1995;7:99–105.
- [49] Hola J, Pikhart M. The implementation of internal communication system as a way to company efficiency. *E+M Ekon Manage* 2014;17:161–9.
- [50] McVittie D, Banikin H, Brocklebanh W. The effects of firm size on injury frequency in construction. *Saf Sci* 1977;27:19–23.
- [51] Hinze J, Raboud P. Safety on large building construction projects. *J Constr Eng Manag* 1988;114:286–93.
- [52] Lin J, Mills A. Measuring the occupational health and safety performance of construction companies in Australia. *Facilities* 2001;19:131–9.
- [53] Hinze J, Gambatese J. Factors that influence safety performance of specialty contractors. *J Constr Eng Manag* 2003;129:164.