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IDENTIFICATION OF FACTORS DETERMINING ACCIDENT RATE IN CONSTRUCTION INDUSTRY

IDENTYFIKACJA CZYNNIKÓW DETERMINUJĄCYCH WYPADKOWOŚĆ W BUDOWNICTWIE

Abstract

The aim of this paper was to present those factors which have a bearing on the accident rate in the construction industry. The main problems afflicting this industry, i.e. the exceptionally high accident rate, the unidentified causes of accidents and the poor reliability of the available data, are highlighted. It has been established that it is difficult to optimally and consciously counteract accidents. In order to attempt to compile a survey, available literature on the causes of accidents in this industry was carried out to compile a coherent and comprehensive list of accident factors dispersed in different publications. The results are presented in a tabular form and serve as an information base for persons interested in identifying the causes of accidents in order to eliminate them, and are the starting point for further research in this field. Moreover, the author concludes that knowledge of the influence of the particular causes on the genesis of accidents is also essential in order to undertake optimal measures at all the stages of safety management.

Keywords: accident factors, accident, hazard, causes of accidents, classification of causes

Streszczenie

Celem niniejszego opracowania jest prezentacja czynników wpływających na powstawanie wypadków w budownictwie. Przedstawiono główne problemy budownictwa, a więc nadzwyczajnie dużą wypadkowość, brak identyfikacji przyczyn wypadków w odpowiednim zakresie, małą wiarygodność dostępnych danych, i postawiono tezę o trudności optymalnego i świadomego przeciwdziałania wypadkom w obliczu występujących niedoskonałości. W celu wypełnienia tej luki, podjęto się studiów dostępnej literatury, poświęconej analizie przyczyn wypadków w tej branży, by na jej podstawie stworzyć spójny i obszerny wykaz czynników rozproszonych w różnych publikacjach celem zawarcia skumulowanej wiedzy w jednym opracowaniu. Zaprezentowane w formie tabelarycznej wyniki stanowią bazę informacji dla osób zainteresowanych poznaniem przyczyn wypadków celem ich eliminacji oraz są punktem wyjścia do dalszych badań. Ponadto autor konkluduje, że w celu przedsiębrania optymalnych kroków na wszystkich etapach zarządzania bezpieczeństwem niezbędna również wiedza na temat wpływu poszczególnych przyczyn na implikowanie wypadków. W tym celu podkreśla wagę podjęcia działań w tym zakresie.

Słowa kluczowe: czynniki wypadkowe, wypadek, zagrożenie, przyczyny wypadków, klasyfikacja przyczyn

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1. Introduction

fact has been highlighted by nearly all the researchers in this field (1), (2), (3), (4). It is enough to analyse statistics from any given country to notice that the frequency of accidents in this industry is much higher than in other sectors of the economy, and also in comparison with the average rate for the whole economy. Figure 1 shows the accident rates for all the sectors of the national economy in Poland in 2011.

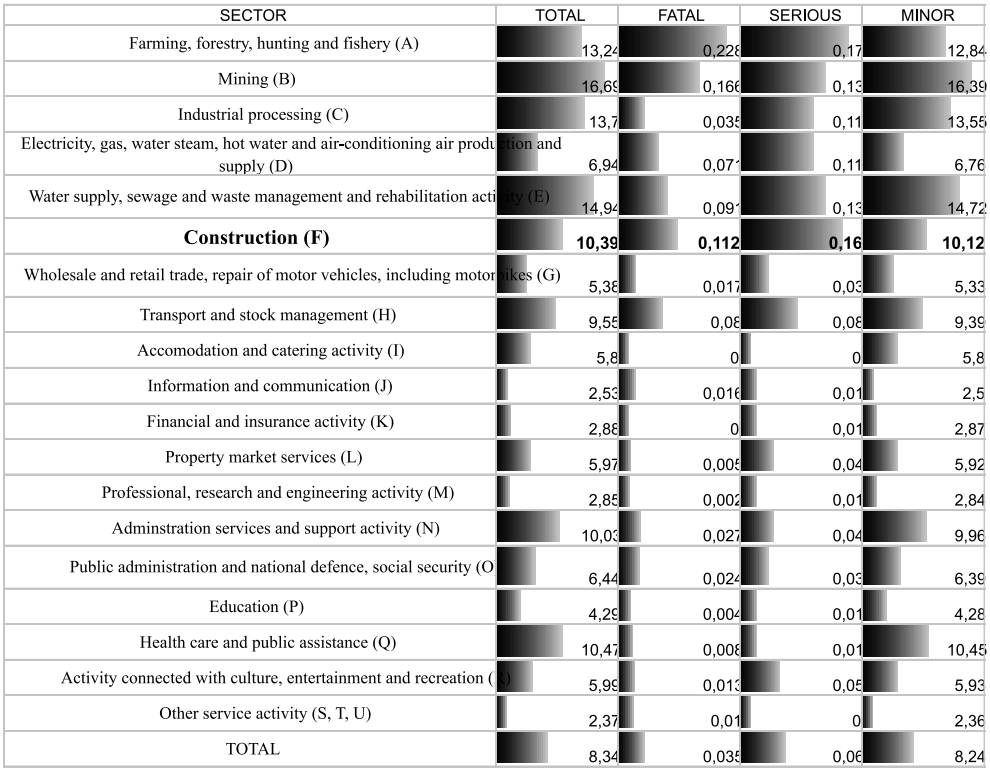

Fig. 1. Rates of (total, fatal, serious and minor) work accidents in 2011, in-house analysis based on Central Statistical Office of Poland (GUS) data

If one examines the variation of the accident rates over time (Fig. 2), a slight downward trend becomes apparent, particularly distinct in the case of fatal and serious accidents. However, one should not jump to optimistic conclusions, since the reliability of the data leaves much to be desired. For example, accident rates published by the Statistical Office of Poland (GUS)are hard to verify because there are no numbers of employees to which these rates refer. Moreover, in the GUS methodology notes one can read that accident rates were calculated for the number of employees as of 31 December without taking persons doing contract work into account. These assumptions may significantly skew the picture of the analysed phenomena since it is well know that due to the seasonal character of construction

work, the average number of employees is completely different than that at the end of December. Similarly, contract work in the construction industry is very common and if this large group of employees isn't taken into account, the results may be misleading. Furthermore, if the number of non-full-time employees is not expressed in terms of the number of full-time employees, the number of employed is overrated relative to the actual time of exposure to hazards, and so relative to the number of accidents. The accident rates presented in Fig. 2, coming from the National Labour Inspectorate (PIP) do not exactly come from this source: since PIP has no data on the number of employees, in order to determine the rates the author related the PIP accident numbers to the numbers of employed reported by GUS (6). However, in this case the results may also be incorrect since the numbers of employed are for the 31 December and do not take contract employees into account.

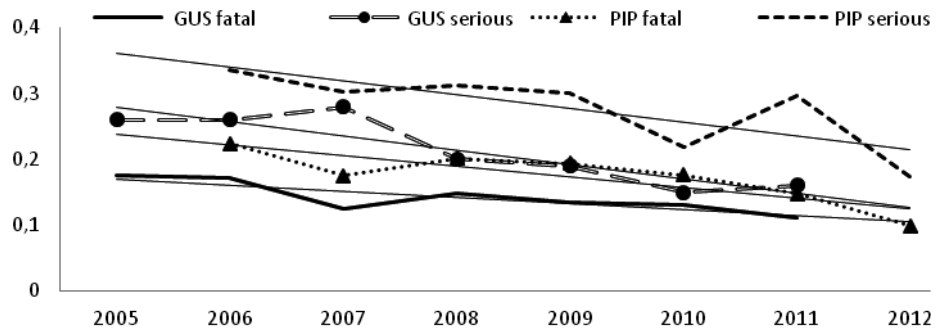

Fig. 2. Variation in fatal and serious accident rates per 1000 persons employed in construction in years 2006–2013, in-house analysis based on GUS (5) and PIP data

Moreover, considering that the causes of an accident are determined by an accident investigation team, made up of the employer and the persons appointed by her/him, it is hard to expect objectivity in the ascertainment of the causes. It is little wonder that the causes relating to the employee and her/his faults predominate, whereas the causes connected with the employer or the management receive marginal treatment (Fig. 3). An increase in the share of *other causes* has also been observed, which suggests that the current classification is incomplete and definitely needs modification. More objective results can be obtained from an analysis of the PIP data on accidents since it is the staff of this institution who determine their causes. Assuming that the accident rate has been decreasing, one still does not know whether it is accidental for the considered period of time or whether it is the result of certain phenomena or deliberate actions.

Considering the doubts about these observed trends, one should give some thought to the causes of accidents. Although the term *cause* is not used in European statistics, the Statistical Accident Card still includes the classification of accident causes (the eight main groups of causes, shown in Fig. 3). Besides the data required by the European Statistics on Accidents at Work (ESAW), collected using the accident at work model suggested by EUROSTAT (7), GUS continues to collect accident data in accordance with the classification above. Whereas PIP investigates accident events, dividing accident causes in accordance with the TOL accident investigation model into technical, organizational and human causes.

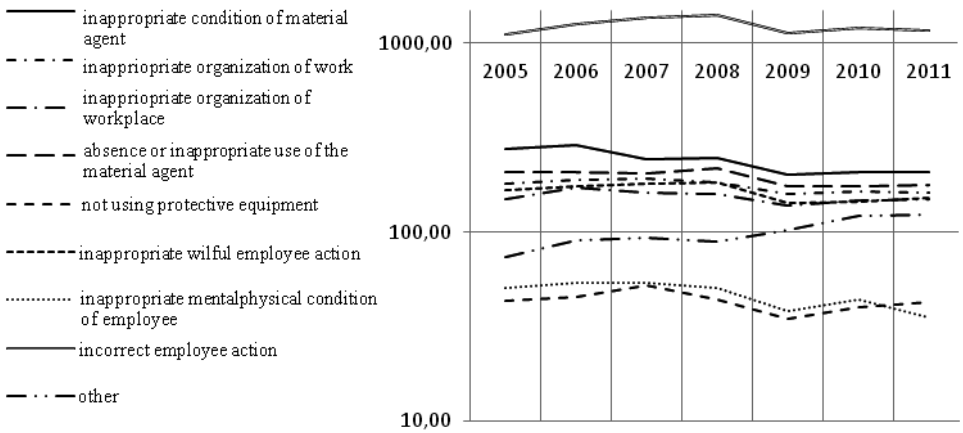

Fig. 3. Groups of causes of accidents in construction, based on GUS (5) data

An analysis of the statistics collected by GUS or PIP shows that they do not cover all variables which have a bearing on the genesis of accidents, but merely the factors directly connected with the construction process, neglecting the ones stemming from the further environment. Without knowing all of the factors directly or indirectly contributing to accidents one is unable to effectively reduce or eliminate the latter. This applies to all the entities which are engaged, within their competence, in eliminating hazards, i.e. employers, investors, employees, inspection units, research units, academic units and the government as well as to all the people by directly affecting individuals, causing their injury or death, or indirectly affecting the whole society which bears the costs of accident-related treatment, insurance or compensation.

2. Description of investigated problem

The problem of safety and accidents in the construction industry is vast and highly complex. Many legislative, sociological, psychological, social, cultural, scientific, technological, organizational, economic, geographic and other factors have a bearing on it. All of these factors should be taken into account in order to create an effective construction project implementation system.

Without knowing all of the factors, including the less visible ones indirectly contributing to accidents, it seems impossible to undertake optimal preventive measures or simply to adopt a proper approach to the problem. Many of the factors are known to the researchers in the field of accidents, but there are some which have not been discovered and classified yet. For example, Okoń (8) divides accident factors into material factors (occurring in the production process) and organizational as well as human factors. It should be noted that accidents in construction work can be caused by structural failures and collapses which, according to Nawrot (9), may arise due to implicit, explicit and unknown factors. Implicit factors are factors of whose existence we are aware, but which cannot be explicitly identified by us. The factors include: culture and social atmosphere, customs, laws, educational system,

education, staffing policy, financial policy and other. Explicit factors are easy to identify and are the subject of studies and analyses. Unknown factors, i.e. factors whose influence we are unable to prove, are omitted, not only in the case of failures and collapses, but also in the case of accident events.

A survey of the literature on the subject has shown that besides the factors already identified which have a bearing on the accident rate, there are many more factors which have not been identified, named and located in the sequence of indirect and direct causes of accidents at work in the construction industry. Therefore one can advance the thesis that the maximum number of accidentogenic factors should provide the basis for accident prevention and for establishing more effective solutions to this problem.

3. Description of investigations

The aim of this research was to identify the factors (scattered in the literature on the subjected) which have a bearing on the accident rate in the construction industry and to present them in a single publication. Despite the large number of works on safety and hazards in the construction industry it is hard to find a single work which would include a sufficiently rich set of factors contributing to the accident rate in this sector. Considering the lack of classification of accidentogenic factors, a wide survey of the literature was carried out to bring together the findings of many researchers together, and to create a comprehensive set of factors contributing to hazards and accidents in the construction industry.

In order to accomplish this task the following investigative methodology was adopted:

1. All of the factors which may contribute to accidents were picked out from each analysed publications and listed.
2. The lists of factors was combined and those repeated or substantially identical factors, coming from different publications, were then removed, leaving only one of them. This task turned out to pose many difficulties, because of the different nomenclature used by the different authors to describe the same factors, the ambiguity of some terms due to the lack of their definitions, the different and subjective classifications of accident factors whereby, e.g., a factor in one publication presented as superior to another in a different publication would occur in a reverse relation.
3. Three main types of factors were distinguished in the set of factors and then divided into kinds and groups, each group comprising several identified factors.
4. An ordered structure of the factors was created, but attempts were made to preserve the original composition used by the authors who presented the widest range of factors. The procedure consisted in forming sets of the most general factors, placing them at the top, and moving the hierarchy down, arranging more and more specific factors directly contributing to accidents.

The set of the factors picked out from the papers analysed by the author were not extended (deliberately) with any additional factors based on his knowledge or experience in order to leave the other authors' original input intact. A similar approach was used towards the composition of the groups and the hierarchy. However, some subjectivity could not be avoided in order to ensure clarity of the presentation. This was also dictated by the greater, (in the author's opinion) accuracy of the proposed terminology, as well as by translation considerations and by the necessary unification of the variously described factors.

4. Results and their discussion

The final results are presented in table 1 which represents the hierarchical structure of accident causes. These qualitative outcomes form a check list of factors. In order to form this check list, an analysis of semantic fields was performed. The method was based on searching for key words among factors from different publication and their categorization according to their role and meaning. Semantic fields of each obtained factor include all similar factors presented in number of publications by different authors. The sources on the basis of which the check list was created are cited next to the qualitative factor. The first level includes the general types of accident factors. On the second level the types are divided into kinds and the latter are divided into more specific groups on the third level. The factors having the most direct bearing on accidents are specified on the fourth level.

T a b l e 1

Classification of factors having bearing on accident rate in construction industry.

WORKING CONDITIONS (27)
Work environment (24) (15) (29)
Workplace (14) (16) (43)
Hazardous conditions on construction site (14) (16) (27) (10)
Workspace (15) (14) (27)
Mess (41) (30)
Uncontrolled/unguarded/hidden hazards (15) (27) (7)
Improper lighting (15) (27)
Changeable/harsh weather conditions (30)
Improper ventilation (27)
Improper traffic control in workplace (27)
Proper welfare facilities (15)
Exposure to noise/illumination/vibrations/temperature/moisture/aggressive environment and substances (15) (14) (22) (30) (43)
Technological environment (41) (15) (29) (43)
Individual protection measures (16) (27) (29) (23) (41)
Collective protection measures (16) (27) (23)
Measures used satisfy relevant requirements (23) (7)
Availability of proper resources and means (15) (7)
Equipment in working order (15) (41) (43)

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Work process (24) (3) (15) (4) (27)
Work specificity (15)
Access to information and advice (15) (27)
Seasonality and variability dependent on conditions (26) (31) (30)
Large number of different lines of business (30)
Communication, information flow, comprehension (4) (24) (10) (2)
Supervision of large number of equipment and materials (4)
Frequent change of place and kind of work 5 (24) (23)
Need for strict control over dangerous operations (4)
Too ad-hoc inspections, especially of small contractors (27) (10) (30)
Disruptions (15)
Large number of subcontractors (4) (20) (19)
Selection of subcontractors (4) (30)
Shifting responsibility, especially on smaller subcontractors (30)
Small/one-off tasks (15)
Difficulties in controlling large number of mutually independent entities (24) (19) (30)
Greater responsibility of employees for themselves and for organization of their work in comparison with other industries (22) (23)
Exposure of migrant, and separated from their families, workers to additional hazards (alcohol, drugs, etc.) (15) (23)
Process characteristics (15) (14) (43)
Size of contracting firms (4) (24) (25) (10) (23)
Project duration (15) (20)
Construction stage (20)
Project character (4) (20) (19) (43)
Implementation methods (27) (20)
Contract awarding system (20)
Project complexity (20) (25)
Terrain constraints (20) (43)
Work process faults/errors/deviations
Time and result pressure, cost reduction and productivity improvement pressure (15) (22) (20) (19) (23) (30)

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Too long work, too heavy workload (15) (22) (10)
Encouragement to quicker work (15) (30)
Welfare support (22)
Stress and psychophysical overload (7) (43)
Harassment and discrimination (22)
Unplanned changes in working time (15) (14)
Inadequate wages (31)
Monotony of work performed (15)
Job uncertainty (22) (23)
Equipment (24) (3) (15) (14) (43)
Faulty design of personal protection measures (15)
Functionality of materials, equipment and tools (15) (14)
Degree of fitting of materials, equipment and tools (14) (27)
Condition of materials, equipment and tools (15) (14) (29) (41)
HUMAN FACTORS (3) (41) (15) (4) (14) (16) (27)
Dangerous behaviour (15) (27) (31)
Errors (15) (43)
Disuse or improper use of protective equipment and protection facilities (16) (27) (29) (41) (31)
Information overload (15)
Improper, chaotic or hurried execution of works (14) (27)
Use of improper technologies (4) (27) (26) (31) (7) (43)
Intentional (15)
Improper execution and maintenance of electrical equipment (41)
Improper use of materials (27) (29)
Lack of order and improper storage of materials and equipment (4) (14) (27)
Non-adherence to rules (15) (43)
Not noticing or lack of warnings or information about hazard (4) (27)
No knowledge of hazards (4) (41) (31)
Lack of repairs and maintenance of tools, equipment, machines and fittings (15) (27) (7)

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Ignoring hazards (29) (41) (31) (30)
Lack of inspection of tools, equipment, machines and fittings or their acceptance even though they do not meet relevant requirements (27) (41) (7)
Deliberate or approved undertaking of risk or dangerous work methods (4) (27) (29) (41) (31) (7) (43)
Qualification (15)
Attitudes (15) (4) (16)
Perceiving risk and exposing oneself to it to keep job (15) (30)
Conformance to and adoption of safe behaviours (15) (4)
Bad or irresponsible behaviour (15) (23)
Team work (15) (16)
Lack of employee vigilance (15) (27) (29)
Becoming complacent (15)
Motivation and morale (15) (16)
Awareness and assessment of situation (15) (27) (7)
Lack of or poor communication (15) (4) (14) (16) (27) (2) (19) (23)
Overconfidence (15)
Undesirable physiological condition (24) (15)
Fatigue and reduced capability of senses (15) (14) (10) (23) (43)
Influence of medicines (15)
Bad and dangerous posture (16) (27) (30)
Health problems, reduced physical strength and flexibility (15) (14) (10) (43)
Poisoning (15)
Stress (15)
Competence (15) (16)
Education and skills (15) (14) (22)
Literacy and calculation skills (15)
Lack of experience (15) (4) (22) (10) (23) (30) (31)
Reaction time (15)
Talents (16)
Age (10)

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Sex (10)
MANAGEMENT &ORGANIZATION (41) (15) (16) (43)
Firm's policy (15) (4)
Kinds of contracts (15)
Competitive contracts (15)
Subcontracting (15)
Organizational structure (15)
Industrial safety system based on outsourcing, trade unions (16) (2) (7)
Employee representation (2)
Resources management (15) (25) (14)
Material resources (15)
Firm's profitability (3) (15) (25)
Proper equipment (15) (29) (30)
Low expenditures on industrial safety (15) (2) (31) (30) (7)
Human resources (15)
Training courses (15) (4) (27) (25)
Hiring and selecting proper employees (15) (4) (25) (23) (31)
Occupational health and safety units and trade unions (29) (41)
Job agencies (15)
Safety control (inspections, audits) (15) (16) (27) (25)
Time management (15) (25)
Safety and organizational culture (15) (4) (2) (23) (30)
Leadership and management (15) (4) (16) (23)
Safety culture and climate (4) (14) (22) (31)
Management commitment to safety (4) (14) (27) (25) (2) (19) (23)
Communication (15) (30)
Role of leadership (15) (16) (19)
Bad management, staffing and decision taking (16) (27) (29) (23)
Setting action goals and directions (16) (27)
Employee commitment to safety (4) (16) (24) (2) (19) (23)

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Procedures and rules (24) (15) (16) (10) (19)
Setting safety policy and concrete actions, tasks, duties and responsibilities (4) (16) (29) (25) (30) (7)
Properly formulated content/language/form (15) (4) (27)
Properly disseminated and implemented (15) (4)
Regulations (25)
Knowledge and observance of labour laws and rules and industrial safety regulations by responsible persons (4) (27)
Participation in safety programmes, competitions and research (16) (10)
Competence in, commitment to and compliance with duties by industrial safety personnel (4) (22) (30) (7)
Lack of, minimal or incorrect safety analysis and risk assessment (14) (16) (30) (7)
Planning (15) (25)
Planning of preventive measures (16) (27)
Taking safety into account in each project (15) (27)
Constant research and design work aimed at safety improvement (14) (2)
Hazard data collection (29) (23)
Disclosing only some causes in accident investigations (27) (7)
Bad system of identifying hazards and dangerous practices (15) (27)
Supervision (15) (27) (41)
Proper supervision by primary contractor (15) (22)
Effectiveness of supervision (15) (4) (14)
Collaboration with other contractors (15)
Bad organization of work, workstations and safety (4) (29) (24) (30) (41) (31) (30)
Tolerance of departures from industrial safety regulations and rules by supervision personnel (4) (41) (31) (30) (7)
Supervision personnel competence (15) (14) (16) (22) (25) (31)
Knowledge and training (15) (16) (27) (29) (24) (23) (30) (30)
Scope of work (14) (27) (7)
Scope of occupational safety 5 (41) (7)
Scope of regulations and duties (4) (41) (7)
Risk assessment (16) (29)

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Experience (15)
Awareness (16) (24) (30)
Abilities (15)
Deliberate neglect of safety (15) (41) (31)
INFLUENCE OF WORK ENVIRONMENT (24) (15)
Legal influences (30)
Effectiveness of regulations (15)
Clarity (15) (4)
Mutual exclusiveness (15)
Not covering all entities (15)
Legal regulations (15)
Adequacy of regulations (4)
Obligatory training courses (15) (4)
Licences and concessions (15)
Market situation (15) (7)
Availability of resources
Time (30)
People (31)
Materials (15)
Equipment (7)
Limited economic capabilities (24) (15)
Reduction of operating costs (31) (7)
Financial standing of firms (7)
Failures by project owners to fulfil their commitments to firms (30)
Migration (2) (41)
Geographic (3)
Social influences (15)
Placing other issues above safety (15) (19)
Social changes (15)
Culture and tradition (24) (4) (14)
Globalization (16)

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Environmental influences (24) (43)
Climate and atmospheric conditions (41)
Food (27)
Sense of safety and comfort (16)
Political influences (15)
Incentives (4)
Promotional campaigns (16)
Internet (30)
Industrial safety institutions (30)
Brochures (30)
Promotion of safety (23) (30) (16)
Collaboration (15) (30)
Group meetings of employees (16)
Social dialogue (30)
Trade unions (15) (30)
Conditioning insurance premium rates on safety level (4) (30)
Training courses in schools (16) (30)
Lack of clauses concerning distribution of duties, responsibilities and consequences relating to industrial safety (4) (30)
Rewarding (4)
Financial (4)
Employee of the Year (4)
Certificates of recognition (4)
Promotion (4)
Prizes in kind (4)
Sanctions and penalties (4)
Financial (4)
Notification of proper authorities (4)
Demotion (4)
Suspension (4)
Dismissal (4)

The classification of accident factors above is the result of an analysis of the publications devoted to the investigation and assessment of hazards in the construction industry. It is obviously not exhaustive and will be extended and modified as the research continues. However, it is important for several reasons. Firstly, it is a set of condensed information (previously dispersed in the literature) which can be readily used, constituting a starting point for further studies. Secondly, it is a kind of check list for all the entities interested in finding out which factors contribute to accidents, whereby their knowledge relating to accidents can be extended. It is also an excellent complement to the accident causes included in the Statistical Accident Card. In the author's opinion, the proposed classification can be considerably extended since many factors mentioned in other sources have not been included. Moreover, the division into the categories and the categorization of factors should not be considered as final since it is merely a proposal or a starting point for optimally shaping the classification and adapting it to specific needs.

5. Conclusions

For the author, the analysis above represents one stage in his research and forms the basis for further studies. From the present stage the following conclusions emerge:

- Accidents in the construction industry are still a major problem which needs to be quickly addressed. This requires the commitment of many social groups interested in reducing accident rates in the construction industry. Awareness of the problem, its consequences and causes (determining factors) are necessary for groups to take proper measures within their competence to effectively reduce accidents at work.
- Because of their subjectivity and simplification, the relevant statistical data, which often misses some key information and are difficult to access, are not a sufficiently reliable source of information to form the basis for preventive measures or for drawing far-reaching conclusions.
- It is not clear what determines fluctuations in the accident rate in the construction industry and whether a momentary downward trend is accidental or due to some other factors, whereby the effectiveness of preventive measures cannot be assessed.
- There is no full classification of causes of accidents, which could form the basis for optimal preventive measures or simply shape proper attitudes. Because of the ignorance of the key factors which contribute to accidents no proper action can be undertaken.
- The study has shown that there are many factors of which we are unaware, indicating a need for their identification.
- Considering the specificity of the construction industry, the variety of construction projects and conditions, it seems reasonable to fit the classification of accident factors specifically to this industry.

In order to make up the above deficiencies it is deemed necessary to further develop the classification, in order to provide knowledge to the parties interested in working towards accident rate reduction. As regard the author, he is conducting research aimed at developing a safety system for the construction industry (and possibly for other industries), based on the proposed classification.

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