OPTIMIZATION OF PORT OPERATION PROCESSES WITH A VIEW OF REDUCING THE RISK OF OCCURRENCE OF WORK ACCIDENTS

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The purpose of this work is to solve certain pressing matters faced by the port operation companies in the port of Constanta regarding the large number of work accidents occurring during the technological processes of loading / discharge of goods from/into containers. Therefore, the main purpose of the this thesis is to reduce the number of accidents due to the existent operation processes by modifying the same insofar as to diminish human intervention to the lowest possible extent.

Keywords: work accidents, risk evaluation, port operation technological process.

1. Introduction

The goods handling operations are the most expensive of all port operations and the most difficult to manage, organize and supervise, since there are a lot of port factors participating therein which have to be coordinated (such as labour force, machines and equipment, tools and devices, different materials storage facilities) there being involved as well many economic agents (owners, port operators, stevedores, forwarding agents, maritime agents machines, equipment and inner transport means owners, the railways, public authorities and so on).

Such elements are manifest in all port operations regardless of the type of transferred goods, but the most complex and the most difficult appear in the not used solid general goods handling, carried with conventional vessels for which the worst port performance is noticed.

This is the main reason which triggered the maritime transport and the ports evolution towards specialization and use of specialized terminals where high performance handling technologies can be applied.

Many ports undertake considerable extension and modernization works in order to assure competitiveness and with a view of increasing the quality of services, of navigation safety and operation of the vessels.

2. The Usefulness of Assessment of Professional Risks

Pursuant to the Law of Safety and Health at Work 319/2006, the managers of economic units are the only responsible for the health and safety of the

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employees, and they are the main actors in the activity of risk prevention and to assure the health and safety at work. They have the legal obligation to secure safety and to protect the health of the employees [1].

In our country the obligation of assessment of professional risks results from the present laws in this respect, duly harmonized with the European Union laws concerning the safety and health at work. Thus, the Law No. 319/2006 enacts chapter III “The obligations of the Employers” the Directive of the Council No. 89/391/CEE/1989.

The starting point in the optimization of work accidents and professional diseases prevention activity in a system is the assessment of the risks in that particular system [2].

Regardless whether a work place, a workshop, a section or an entire trading company are considered, such an analysis allows the dangers to be known, quantified and hierarchically structured according to their dimension as well as to assign the resources for priority measures in an efficient way [3].

The risk assessment implies the identification of all risk factors in the analyzed system and the quantification of their dimension based upon the combination of two parameters: the probability of occurrence thereof and the seriousness of the maximum possible consequence (the most frequent) upon the human body. In this way, partial risk levels are obtained for every risk factor and global risk levels respectively, for every work place, as well as a global aggregate risk level for the entire analyzed system.

The object of risks assessment is to allow the employer to adopt adequate prevention/protection measures concerning [4]:

- Prevention of professional risks
- Training of the employees
- Information of the employees
- The implementation of a management system which allows the actual application of the necessary prevention / protection measures.

The basic goal of the assessment of the risks always remains the prevention of professional risks [5]. Their elimination is not always possible and then the same must be decreased until reaching the value of certain residual risks which must and can be controlled.

The reassessment of professional risks is also done whenever changes occur in the work system (organization of work, implementation of new materials, equipment, methods, procedures, etc.) or whenever the people involved request it.

During the assessment and thereafter it must be observed that the risk should not be transferred to other areas of the work system and that the elimination of a riks does not generate new problems [5].

Knowing and assessing the risks enables the corporate entity to take actions which lead to their decrease or elimination. To invest in the prevention of work accidents and professional diseases means to invest in the improvement of the company business.

3. Presentation of the method of assessment of the risks of injury

The principle of the method consists in the indentification of all risk factors in the analyzed system (the work place) on the basis of pre-established check lists and the quantification of the risk dimension according to the combination between the seriousness and the frequency of the maximum predictable consequence [6].

The risk factors are all the factors of the work system which are likely to act upon the health or integrity of the workers and which can inflict injuries. This is what most people would call in everyday language hazards or hazardous situations. In this respect the European norm EN 292-1 defines hazard, the hazardous situations or hazardous events associated with the work process (risk factors) as being a “cause capable of inflicting an injury or an attack on health”. This definition represents a qualitative appreciation of risk used in the identification thereof [6].

Safety is defined as being protected against any danger. Risk and safety are strongly correlated and they exclude one another.

The concepts of safety and risk are opposite and they are connected by a hyperbolic equation [7]:

$$R = 1/S \quad (S = \text{safety};\ R - \text{risk}) \tag{1}$$

Since the risk cannot be null (infinite safety) it must be determined what pairs of probability of occurrence / seriousness of consequences can assure an acceptable risk level (Fig. 1.).

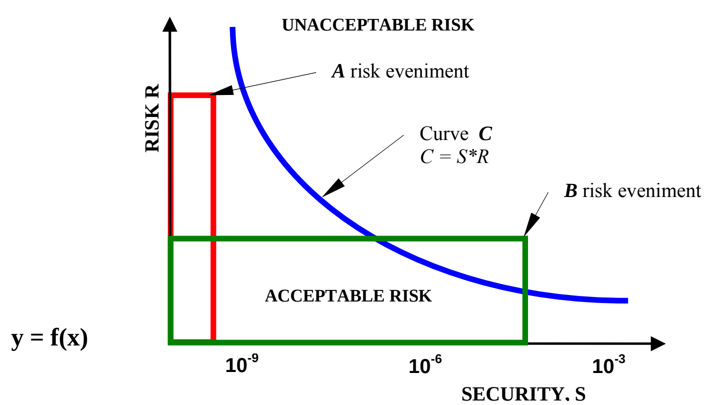

Fig.1. – Relationship risk – security

Risk = Pursuant to the European norm EN 292-1 the risk is defined as being "the combination between the probability and the seriousness of an injury or attack on health likely to occur in a hazardous situation".
Seriousness = It is appreciated according to the standard MIL-STD-882 C by evaluation of the consequences of the most serious accident likely to be caused by that particular risk factor.
Probability = According to the standard MIL-STD-882 C probability represents the frequency of occurrence of the undesired event and the same can be described as a potential occurrence within the time unit or related to the population, element or situation.
The risk level = The risk level is an absolute quantitative indicator which allows following evaluation to know to what extent the safety of work system is acceptable or not in terms of the possibility of occurrence of accidents and professional diseases
Exposure = Exposure to risk factors represents the duration in time or the frequency in time to which the performer is exposed to a risk factor and the level of such exposure. The value of this constant presently accepted in Romania is 3.5.

The main object of the assessment is to determine the unacceptable risks and to bring the same within the range of acceptability [8].

The method of assessment of the risk level and its classification as acceptable or unacceptable risk has the advantage that it can be applied both to already existing work systems and to the ones being under construction – design [9]. The determination of the curve of acceptability of risks (marking the limits of acceptable risks) is a difficult matter. The same is done by a strategic decision starting either from the cost of human life or from the comparison with different risks already accepted.

4. The concrete application of the method to the work system

Starting from the deficiencies and the shortcomings of the methods of risks evaluation based upon inspections and verifications and the reliability and ergonomy of systems, Pece, [7], brings important contributions to risks evaluation in the human – machine system, by elaborating in the 90' a theoretical model of the origin of work accidents and professional diseases, implying all the components of the work system and a global theoretical model of the dynamics of the accident in the work system under the action of two causes, the objective one and the subjective one.

These contributions finally allowed the elaboration of an "a priori" analytical quantitative method of evaluation of the risk/safety level, which has a great extent of generalization and application, being mainly and exclusively centred upon the improvement of the work conditions in terms of work safety [7].

The goal of the method is the quantitative determination of the professional risks for a place of work, workshop, section, unit, and the purpose is to obtain a centralizing document called “The work place evaluation record” which contains the partial risk level per each global risk factor per work place and the global aggregate of the company and which is the basis of elaboration of the plan of measures. The evaluation method is strict, practical and accepted by the decision taking factors in Romania, the transnational economic units, and the National Pensions and Social Security House [7, 10].

The analytical method of evaluation of the level of professional risks considers that work accidents and professional diseases are aleatory events, their occurrence can be estimated only in a probable way and they are in a causality dependence with the elements of work system [9] (performer, job task, means of production, work environment).

The area of occurrence of the work accident and professional disease is the work process, containing the work system which has possible malfunctions and disorders, which turn into potential injury and/or professional disease, i.e. risk factors.

5. Risk evaluation – Loading timber packages into container in the “classical” system by means of stackers

5.1. The work process

The analyzed work process consists in the handling and stowage of timber packages from the port platform into 20’ or 40’ containers using mechanized means for lifting, transportation and stowage [11].

The technological process of loading the container is made of the following stages:

Stage 1: The goods are carried from the storage place to the loading place with trailers which are loaded by means of four stackers with a capacity of 4.5 tf.

Stage 2: A platform (a sheet-metal plate) is placed at the entrance of the container – such operation being carried out by dockers manually or by means of a fork lift.

Stage 3: The cargo is placed on the platform and formed taking into consideration the height of the container (the load is made up of 2 parts for the containers of 40’ and one part for the containers of 20’). (Fig.2.)

Stage 4: Hooking the packages in a lashing by the front forks of the fork lift – such operation being carried out manually by the dockers (Fig. 2.).

Stage 5: Pushing the cargo into the container by means of the fork lift and repetition of these operations until the termination of loading of the container (Fig. 2.).

Fig. 2. – The loading stages of the timber into the container

Stage 6: Lining up the timber packages for an optimum stowage thereof, both in the container and in order to enable closing the doors of the container - such operation being carried out by the dockers by means of wooden pieces fixed manually, and the lining up is done by pushing these wooden pieces with the tips of the forks of the fork lift.

The operation is repreated until the termination of loading operation of the container.

Stage 7: After the completion of loading the container is handled by means of container handling stacker or with a truck crane provided with a spreader.

5.2. The component elements of the assessed work system

The work equipment:

- Storage platforms, warehouses, operation berths, quays;
- containers of 20’ and 40’;
- Spreader type stackers for container handling, truck crane of type RDK (a spreader type device can be attached thereto), fork lifts of 2.5 – 5.5 tf, tractors of 65 HP with trailer of 20 - 40 t, tractor units with semi trailers;
- Goods handling tools and devices: joining shackles, cables, ropes, hooks of 3 – 12 tf; spring lines (cables with soft eyes); slings (textile tapes), pallet hooks, tools and devices to remake the lashes, the slings, the pallets, the access ladders, pliers and scissors to cut wire;

The task of the job:

- To check the binding means and the fastening devices, thereby watching:
  - The use of textile lashings, springs, slings, fastening devices with the maximum admitted load marked upon them;
  - The binding units or the fastening devices should not manifest any wear and tear marks beyond the admissible limits;
- Achieves the binding and fastening of the loads to the device attached to the fork lift or truck crane, using means of binding and fastening devices in compliance with the shape, dimensions and weights of the respective loads;
- Achieves the binding of the loads so that they are in perfect balance;
- Manages the handling of the goods with lifting equipment, using the signaling code for the load rope men;
- Achieves the stowage of the goods in the containers observing the stowage technology, using separation elements (chocks, wedges) and assuring the stability of the stacks;
- Performs manual handling operations by pulling, pushing, lifting, carrying heavy loads, whenever the same are included in the technologic process;

The work enviroment:

Most of the time the activitiy is carried out in outdoor areas, so that the work environment presents the following characteristics:

- High temperature in summer, and low during winters;
- Snow, snowstorms, block frost, ice covered surfaces;
- Temperature variations during the work shift (warehouses, platforms, the holds of the vessels);
- Air currents;
- Strong wind with values ranging between 10 and 30 m/s;
- Background noise specific for port berths and platforms;
- Marine environment;
- Exhaust gases from the fork lifts working in containers or on the platform;
- Low lighting levels durin night work (on the platforms, in containers) – the lighted areas alternating with dark areas

The performer:

The performer of the technological process of loading and stowage of the timber packages in order to load the same into the container has the trade of dock worker or dock machine operator.

5.3. Identification of the specific risk factors of the work place

The calculation (INCDPM method) of "***Global risk level of the work place***" was done in relation (1) as a result of "***The work place evaluation record***" where “***the risk factors were identified***” for the work place specific [17] for the trade of docker and the concrete way of their manifestation upon the the human bodyas presented in Table 1.

Table 1

Identification of risk factors

The risk factors and the concrete form of manifestation of risk factors (description, parameters)	
The component of the work system – WORK EQUIPMENT	
Mechanical risk factors	
F1 – Being hit by the means of transport while moving through the terminal	4
F2 – The manoeuvres of the fork lifts, truck cranes, quay cranes, truck loaders, tractors, done in the work area	4
F3 – Fall of the loads from heights due to breaking of the binding or fastening devices	4
F4 – Collapse of stacks – crushing	4
F5 – Slippery grounds – fall from height while managing the lifting equipment for container loading	4
F6 – Dangerous surfaces and edges during the operation of binding the goods in slings - cut injury, stinging	4
F7 – Slings made up of unequal sized parts – fractures, crushing by fall of the parts	4
F8 – Collision between the fork lifts driven with no visibility on the platform, in the warehouses, and storage areas – fractures of the limbs	3
F9 – Swinging of the hook of the hoisting devices for long loads – crushing, amputation of limbs	4
F10 – Blockage of the safety devices of the work equipment (load limiting, turning, arm opening, braking devices) – Striking, crushing	3
Thermic risk factors	
F11 – Low temperature during winter of the objects or the sufaces of the goods/equipment – frost bites	3
The work system component – THE WORK ENVIRONMENT	
Physical risk factors	
F12 – High temperature of the air during summer and low during winter – acute viroses	3
F13 – Snow, snowstorms, block frost, ice covered surfaces – breathing affections, sprains, fractures	3
F14 – Temperature variations during the work shift (platforms, warehouses, the holds of the vessels)	3
F15 – Air currents - breathing affections	3
F16 – Background noise specific for port berths and platforms – hearing impairment	3
F17 – Low lighting levels durin night work on platforms, in containers, the lighted areas alternating with dark areas – decrease of visual acuity	3
Chemical risk factors	
F18 – Toxic exhaust gases from the equipment used for work at containers – asphyxia	4
Special character of the environment	
F19 – Marine environment – premature wear of the body	3
Work system component – THE JOB TRASK	

Inadequate contents	
F20 – Use of improvised tools – overstrain of the body	4
Physical overstrain	
F21 – Performs manual handling operations by pulling, pushing, lifting, carrying heavy loads – dorsal – lumbar affections	5
F22 – Forced positions upon lashing the goods to make the slings – affections of the vertebral column	3
Psychic overstrain	
F23 – Great work rhythm, repetitive operations, short cycle	3
The work system component PERTAINING TO THE PERFORMER	
Wrong actions	
F24 – Moving or stops in dangerous areas – in the access ways of the vehicles, on the railway, under the load of the cranes, etc.	4
F25 – Climbing or descending in prohibited areas	4
F26 – Use of wrong procedures in binding and balancing the loads in the hook of the crane	5
F27 – Failure of synchronization of operations during the manoeuvres performed in the containers	4
F28 – Failure of synchronization of the operations of binding and directing the loads in the hook of the crane	5
F29 – Comunications likely to generate accidents between the members of the dockers team	5
F30 – Using open fire in closed areas (warehouse, storage areas)	3
F31 – Falls on the same ground level by slipping, stumbling, loss of balance – fractures	4
F 32 – Falls from height, by stepping into the void, loss of balance, slipping	4
Omissions	
F33 – Failure to perform operations to assure safety at work	5
F34 – Failure to use the personal safety outfit and the other means of protection granted by the employer	5

The global risk for a place of work is computed according to the formula (INCDPM method):

$$N_{rg1} = \frac{\sum_{i=1}^{34} R_i \times r_i}{\sum_{i=1}^{34} r_i} \tag{2}$$

where N_{rgl} = is the level of global risk per place of work
r_i = is the rank of the risk factor "i"
R_i = the risk level for the risk factor "i"
n = the number of risk factors identified

For the place of work – Loading of timber packages in the "classic" system the global risk level relation (3) calculated by means of formula (2) is:

$$N_{rg1} = \frac{\sum_{i=1}^{34} R_i \times r_i}{\sum_{i=1}^{34} r_i} = \frac{0(7\times7)+0(6\times6)+6(5\times5)+15(4\times4)+13(3\times3)+0(2\times2)+0(1\times1)}{0\times7+0\times6+6\times5+15\times4+13\times3+0\times2+0\times1} = \frac{507}{129} = 3{,}93 \tag{3}$$

5.4. The interpretation of the results of the assessment

The global risk level calculated for the work place is equal to **3.93**, such value classifying it in the category of ***medium risk level*** of the work places.

The result is supported by the "Evaluation Record" where it can be observed that out of the total number of 34 risk factors identified (Fig. 3.), **21** of them exceed, as partial risk level, the value 3:0, the same being classified as follows:

0 – are classified in the category of **maximum** level risk factors,
0 – are classified in the category of **very high** level risk factors,
6 – are classified in the category of **high** level risk factors,
15 – are classified in the category of **medium** level risk factors, and the other
13 – are classified in the category of **low** level risk factors**.**

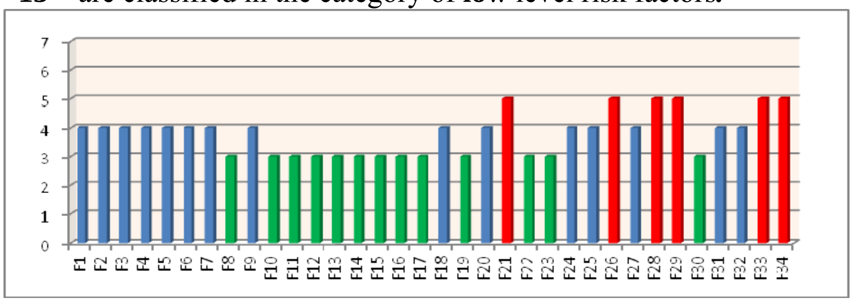

Fig. 3. – Partiual risk levels per identified risk factors

As far as the distribution of the risk factors per generating sources is concerned, the situation looks as follows (Fig. 4.):

1)	**– 32.35 %** factors specific for the *means of production*;
2)	**– 23.53 %** factors specific for the *work environment*;
3)	**– 11.76 %** factors specific for the *task of the job*;
4)	**– 32.36 %** factors specific for the *performer*.

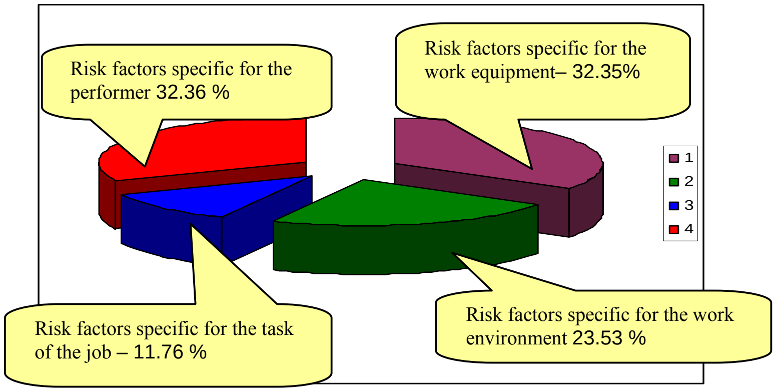

Fig. 4. - The share of the risk factors identified according to the work system

By analyzing the **Evaluation record** one finds out that **58.82%** of the identified risk factors can have irreversible consequences upon the performaer (***DEATH or INVALIDITY***) as follows:

- 47.06 % - death
- 11.76 % - invalidity

In order to decrease or eliminate the 21 risk factors (located in the unacceptable field) it is necessary to change the technology for the analyzed work place, such change being proposed in the next paragraph.

6. Achieving the investment by purchasing an installation provided with an electrically operated conveyor belt

Following the proposal of improvement of the technological process of loading the timber into containers, an ACTIW LOADPLATE loading installation was purchased, provided with an electrically operated conveyor belt.

6.1. Description of Actiw LoadPlate device

The Actiw LoadPlate (ALP) loading system is designed to be operated at the premises of the client.

The ALP loading system (Fig. 5.) is mobile, so that it can be easily moved to the area where loading of the containers takes place. The cargo to be loaded is deposited on the loading plate by means of fork lifts, cranes etc. The emplty container is brought with its doors open and it is positioned on a special platform representing an extension of the ALP loading system. The loading system is attached to the container by its angles. This loading system is destined only for this type of loading configuration.

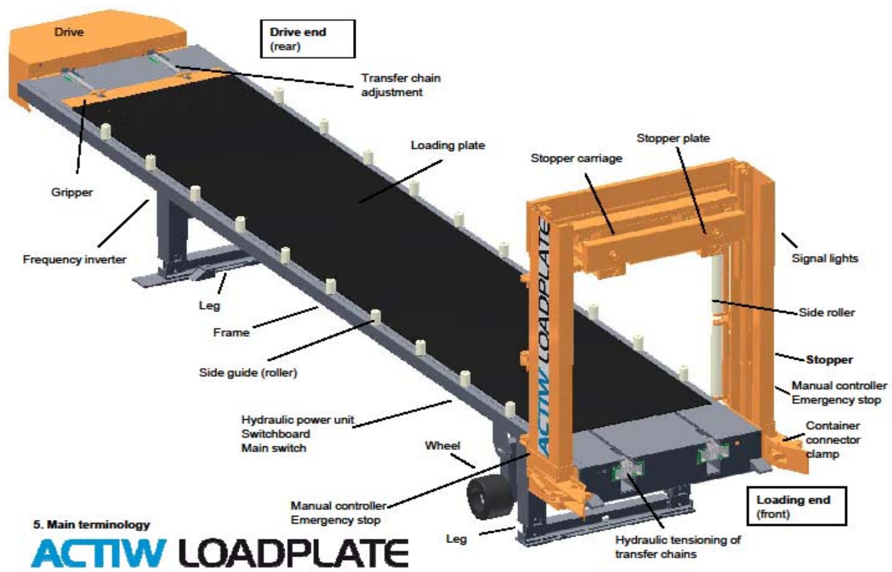

Fig. 5. – The Actiw LoadPlate device

A plastic material loading plate is moved on the frame of the loading system and it is driven by transfer chains. The cargo to be loaded is put on that plate by means of a fork lift, crane or other similar equipment and the plate is pulled into the container together with the cargo. A stopper plate driven by hydraulic cylinders blocks the cargo in the container while the loading plate is pulled out. The stopper plate is fitted in a stopper carriage which is moved vertically by telescopic cylinders.

6.2. The optimized work process

The optimized technologic process is carried out in five stages as compared to the seven ones of the former process.

Stage 1 : The cargo is brought from the storage area to the loading place by means of two fork lifts having a 4.5 tf capacity.

Stage 2: Placing an empty container on the platform of the loading installation.

Stage 3: Stacking the timber packages on the conveyor belt (Fig. 6.)

Stage 4: Starting the belt in order to push the packages into the container (Fig. 6.)

Stage 5: After the completion of loading the container is handled by means of the container handling stacker or by a truck crane provided with a spreader and put on transportation vehicle to be moved to the ship.

Fig. 6. – The loading stages of the container by means of ALP

6.3. Revaluation of risks – Identification of risk factors

As a result of the change of loading technology of the timber packages into the containers the revaluation of the risk factors specific to the new work place was done. The following aspects were found:

- A number of 15 risk factors were eliminated: 4 with partial high risk level - 5 (F21, F26, F28, F29); 9 with medium level 4 (F3, F5, F6, F7, F9, F18, F20, F25, F32); 2 with level 3 (F22, F30),
- Only 9 factors were identified, all factoirs with partial high level -5 were eliminated; 3 factors remained with the same level and the rest of 16 have a lower risk level.

The calculation of ***„The global risk level of the work place"*** was done in the relation (4) as a result of "***The evaluation record of the work place***" for the trade of docker.

$$N_{rg1} = \frac{\sum_{i=1}^{19} R_i \times r_i}{\sum_{i=1}^{19} r_i} = \frac{0(7\times 7)+0(6\times 6)+0(5\times 5)+5(4\times 4)+13(3\times 3)+1(2\times 2)+0(1\times 1)}{0\times 7+0\times 6+0\times 5+5\times 4+13\times 3+1\times 2+0\times 1} = \frac{201}{61} = 3{,}29 \qquad (4)$$

6.4. Interpretation of the results of the evaluation:

The global risk level calculated for the work place equals **3.29**, such value placing it in the category of workplaces with ***medium risk level***.

19 risk factors identified (Fig. 7.), of which **5** exced, as partial risk level, the value 3:0 being classified as follows:

0 – are classified in the ***maximum*** risk factors category,

0 – are classified in the ***very high*** risk factors category,
0 – are classified in the ***high*** risk factors category,
5 – are classified in the ***medium*** risk factors category
13 – are classified in the ***low*** risk factors category
1 – are classified in the ***very low*** risk factors category

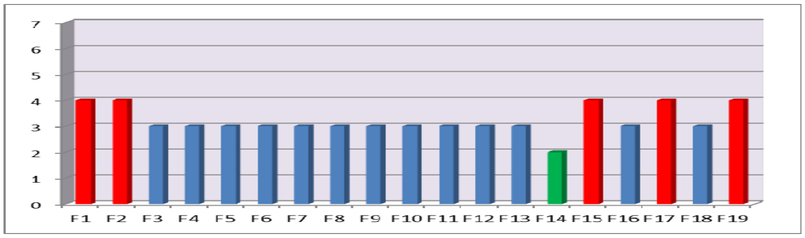

Fig. 7. – Partial risk levels per identified risk factors

As far as the distribution of the risk factors by generating sources is concerned the situation looks as follows (see Fig. 8**.**):

1) – 31.57 % factors specific for the *means of production*;
2) – 36.84 % factors specific for the *work environment*;
3) – 5.26 % factors specific for the *task of the job*;
4) – 26.33 % factors specific for the *performer*.

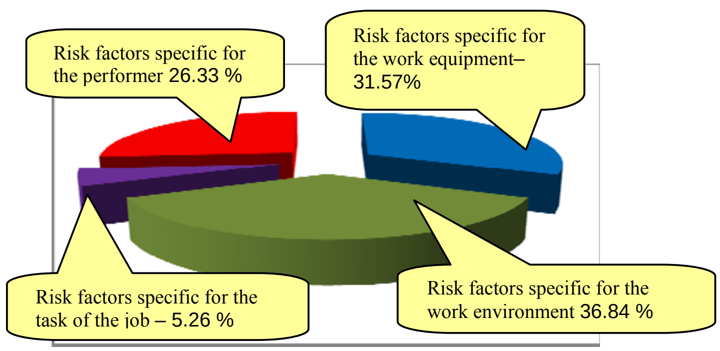

Fig. 8. - The share of the risk factors identified according to the work system

By analyzing the **Evaluation record** one finds out that **57.89%** of the identified risk factors can have irreversible consequences upon the performer (***DEATH or INVALIDITY***) thus:

- 47.36 % - death
- 10.53 % - invalidity

7. Conclusions

When designing any port operation technological process, the stages in which possible causes for the occurrence of work accidents appear must be known to enable the prevention of the risks which can affect the health and safety at work of the staff involved.

As a result of the study carried out we proposed a technical solution on optimization technology of timber loading container using a device equipped with a powered conveyor.

After changing of technology the following conclusions are drawn:

- ⇨ ***The injury risk level of 3.93 decreases significantly going under the acceptable limit (3.5) i.e. 3.29,*** and implicitely ***the level of work security increases.***
- ⇨ ***The increase of the quality of services*** rendered by the port operator by eliminating the causes for the depreciation of the timber packages both during their transportation from the field to place of loading and during their handling for loading into the container.

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