SAFETY AND PRODUCTION: AN INTEGRATED PLANNING AND CONTROL MODEL

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ABSTRACT

This paper presents a safety planning and control model (SPC) that has been integrated to the production planning and control process. The model integrates safety into three hierarchical levels of production control. Safety long-term planning starts with the preliminary hazard analysis (PHA) of construction processes. These plans are detailed and updated at both medium-term and short-term planning levels. The main performance measure adopted for safety evaluation at the short-term level is the Percentage of Safe Work Packages (PSW), which monitors the degree in which work packages are safely carried out. The model also proposes a participatory mechanism that allows workers to point out existing risks as well as to evaluate risk controls. This paper discusses an empirical study in which the model was implemented in the refurbishment of an industrial building.

KEY WORDS

Safety, production planning and control, operations management, performance measurement.

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INTRODUCTION

In spite of the high costs of work accidents, many construction companies adopt as their only health and safety management strategy the compliance with mandatory regulations. However, only being in compliance with these regulations might not be sufficient to guarantee excellence in health and safety performance, as they cover only minimal preventive measures.

In Brazil, the main health and safety regulation related to construction industry is the NR-18 standard (Work Conditions and Environment in the Construction Industry). Health and safety planning appears as a core requirement in this standard: a health and safety plan for the whole project, named PCMAT (Plan of Conditions and Work Environment in the Construction Industry), is required. Since NR-18 was established in 1995, most companies have produced such plan only to avoid fines from governmental inspectors and do not effectively use it as a mechanism for managing site safety. Its main shortcomings are presented below:

a) PCMAT implementation is usually regarded as an extra activity to managers, since it is not integrated to routine production management activities. NR-18 does not require its integration to other plans, except for site layout planning;

b) PCMAT is usually produced by outside experts who do not work on a permanent basis for the company. Production managers, subcontractors or workers are not usually involved ;

c) PCMAT does not usually take into account the uncertainty of construction projects. A fairly detailed plan is produced at the beginning of the construction stage and this is not usually updated;

d) Formal control of PCMAT implementation is rarely carried out;

e) PCMAT emphasizes physical protections, normally neglecting the necessary managerial actions (for instance, implementing proactive performance indicators) that are needed to achieve a safe work environment; and

f) PCMAT does not induce risk elimination through preventive measures at the design phase.

In Europe, Directive 92/57/CEE (Temporary and Mobile Construction Sites) requires a health and safety plan similar to PCMAT (Dias and Fonseca 1996), and it has similar problems pointed out for PCMAT in Brazil (items *b* to *d*). Regarding item *f*, although the European regulations require safety considerations in design (especially in the design of product), this approach has been reported as difficult to be implemented (McKenzie et al. 2000).

Such shortcomings in both conception and implementation of mandatory plans indicate that it is necessary to improve safety planning and control (SPC) methods, beyond what is required by the regulations. This statement is supported by some studies that have investigated causes of accidents and good practices to avoid them. Suraji et al. (2001), for example, based on the analysis of five hundred accidents in the UK, found that planning and control failures were related to 45.4 % of the accidents. A similar study carried out by the Construction Industry Institute (Liska et al. 1993) found that, among several preventive actions that had been used by the industry, detailed safety planning was necessary for achieving the zero accident target. However, Agaj (2000) suggests that safety planning is neither organized as a managerial process nor it is consistently linked to the production planning process. As a result, the potential benefits of safety planning are likely to be sub optimized by industry.

In spite of being suggested by a number of authors, such as Hinze (1998) and Mc Collum (1995), few studies have investigated the fully integration of safety into production planning. Ciribini and Rigamonti (1999) and Kartam (1997), for instance, discussed the introduction of safety measures into construction plans, using CPM or line of balance planning techniques. This approach tends to have little impact, since it has been accepted that planning should not be limited to the application of techniques for generating plans. By contrast, planning should be regarded as a broader managerial process composed by several stages, including data collection, implementation of corrective actions, and information diffusion (Laufer and Tucker 1987). Also, some of the main requirements for effective production planning and control, such as hierarchical decision making, cooperation, continuity and a systemic view (Laufer et al. 1994), are requirements also for safety management.

Thus, there seems to be an opportunity for improving SPC methods based on concepts and principles that have been successfully used in production planning and control (Ballard 2000; Laufer et al. 1994; Laufer and Tucker 1987). This paper presents a Safety Planning and Control (SPC) model that integrates safety management to the production planning and control process. The model was developed through an empirical study, which is reported in the following sections.

RESEARCH METHOD

The research strategy adopted in this study was action research, because the aim was to devise and test the safety planning and control model in a real construction environment. Action research is a strategy for obtaining both knowledge and change in social systems at the same time. It is a cyclic process, involving the diagnosis of the problem, planning, action, and an assessment of the results. In this approach, the main focus of the investigation is the result of an intervention in the subject being studied (Eden and Huxham 1996). The action research empirical study was preceded by an exploratory case study, in which the SPC model main features and tools were roughly established (Saurin et al. 2001).

The empirical study was divided into six stages: (a) integration of safety into long-term planning; (b) integration of safety into look-ahead and short-term planning; (c) implementation of a risk identification and control cycle based on workers perceptions; (d) development and implementation of safety performance indicators; (e) introduction of a monthly safety performance evaluation meeting; (f) realisation of a seminar for discussing the final results of the study.

CONTEXT OF THE EMPIRICAL STUDY

DESCRIPTION OF THE COMPANY AND THE SITE

The empirical study took place in a small sized construction company, which was chosen due to two main reasons: it had a fairly well structured production planning and control process and it was particularly interested in successfully implementing SPC. This interest was partially due to its clients, who had fairly strict safety requirements.

The project chosen for the study was the refurbishment of a steel mill building, in the Metropolitan Area of Porto Alegre, in the South of Brazil. This specific project was selected because it was assumed to be a very demanding project in terms of safety management.

The duration of the project was approximately six months. The implementation of the model took place during the first four months of the project. As in many industrial refurbishment projects, the steel mill production was not interrupted to allow the construction project to be undertaken. As a consequence, the steel mill health and safety risks also affected construction workers. Besides, the main steel mill building was relatively old, and had not been designed for maintenance and repairs to be easily performed. In order to comply with contractual requirements, the construction company assigned a full time safety specialist to work on the site.

EXISTING PRODUCTION PLANNING AND CONTROL PROCESS

The existing production planning and control system was based on the Last Planner Method of Production Control (Ballard 2000). There were four planning and control levels: one-week and one-day short-term commitment planning, three-week look-ahead planning, and long-term planning.

At the short-term level, work packages were assigned to different crews, and an initial negotiation concerning the release of working areas took place in weekly meetings. Due to the variability of the work environment, caused by the interference between the steel mill production and the construction process, weekly plans needed to be re-evaluated in daily meetings. In such meetings, the final definition of working areas for each crew was made, and, based on that, the client provided work permits. The PPC - Percentage of Plans Completed - indicator (Ballard 2000) was collected on both weekly and daily basis.

Regarding the look-ahead planning level, its main function was to support the removal of constraints related to work packages. A three-week plan was produced weekly, containing a list of constraints (e.g. space, materials, labour and equipment), and the deadline for its removal. Finally, the master plan, including the whole construction project was updated on a monthly basis.

EMPIRICAL STUDY DEVELOPMENT

INTEGRATION TO LONG-TERM PLANNING

Long-term safety planning was carried out using the construction stages established in the long-term production plans as a basis. For each construction stage (e.g. bricklaying, roofing, etc.), a plan was produced using the Preliminary Hazard Analysis (PHA) technique. This technique is widely used in safety planning (Kolluru et al. 1996) dealing with three out of the four major stages of risk management: risk identification, risk evaluation and risk response. Risk monitoring is the fourth one. These four stages altogether correspond to the risk management cycle (Baker et al. 1999) that should be repeated throughout the project. In the SPC model, long-term safety plans were categorized into two groups:

- the first group involves plans whose risks cannot always be clearly associated to a specific work package, such as, for example, plans related to temporary facilities (lock rooms and bathrooms), common circulation areas, equipment for materials hoisting, ironwork shop, formwork shop, and mortar production mixer. Such risks cannot be assigned to a specific work package, since, in reality, they are concerned with several of them;
- the second group involves plans whose risks can always be clearly associated to specific work packages. The majority of plans were included in this category, such as painting, replacement of the roof structure and tiles, and bricklaying. In this group, specific plans might be produced for families of activities that take place in different construction stages. For instance, since welding activities are performed in several stages, it is easier to produce a specific safety plan for all of them instead of producing several similar PHA.

A member of the research team was assigned responsibility for producing the first draft of the safety plans. These were refined through meetings involving a member of the research team and the following stakeholders: the site manager, the safety specialist, both subcontractors and client representatives. Foremen also gave their contributions when the plans were discussed in a NR-18 mandatory monthly safety meeting. The participation of different stakeholders was essential, since they could provide different insights about risks, allowing safety plans to be more realistic and effective. The main steps for producing the safety plans are presented below:

- establish the necessary process phases to be undertaken: both conversion (for instance, place bricks on the wall) and flow activities (for instance, moving or storing materials) should be considered, as suggested by Koskela (2000);
- identify the risks: risks of any nature (e.g. health risks, ergonomic risks, and environmental risks) must be considered in each step of the process. This is a critical task, since if a risk is not properly identified it cannot be controlled. The effort to identify risks can be supported by tools such as checklists and brainstorming, as well as technical literature or plans from past projects (Baker et al. 1999). In order to establish a common language for all plans, it is also helpful to adopt a risk classification (e.g. caught in, stuck by, etc.) at this stage. In addition, different stakeholders need to be involved, as mentioned above, since they are all valuable sources of information;
- define how each risk will be controlled: considering that safety control will be based on what has been written down in the plans, it is important not to establish a control if there are no resources to apply them or if they are not considered to be necessary. Although the aim should be to eliminate all risks, such objective will be rarely possible and residual risks will remain. The solution is to keep such residual risks within an acceptable level. Managers are the ones who must decide what is acceptable or not, following regulations as

minimal requirements. In this study, no formal risk evaluation was carried out for establishing the magnitude of the safety measures. This could be done, for instance, by estimating the degree of severity and the probability for each hazard and decide whether the resulting risk is acceptable or not. This procedure was not considered to be cost-effective at this stage, mostly due to the subjectivity involved in this activity (Tah 1997).

INTEGRATION TO LOOK-AHEAD PLANNING

Safety constraints were systematically included in the look-ahead constraint analysis, which was carried out weekly, considering a three week planning horizon. In this way, safety constraints were made more visible in advance, avoiding stoppages in construction processes. At this planning level, only the production manager, the safety specialist and a member of the research team were involved.

An example of safety related constraint was *purchase guard rails components for fall protection system*. Someone was assigned responsibility for the purchase of such item and a deadline was established. The installation of the guard rail was also regarded as a constraint, once a number of work packages should not be started before it.

In this study, safety constraints involved five categories of safety related resources: safeguards, personal protective equipment (PPE), design of safety facilities, training, and space. Table 1 presents examples of resources for each of these categories. These resources might be associated to one or more constraints. As an illustration, the constraints related to safety signals might include either the manufacturing of the signal devices or their installation on site.

Based on five cycles of constraint analysis carried out in the empirical study, safety constraints represented on average, 41 % of all constraints.

Table. 1. Examples of safety related resources.

Category	**Examples of resources**
Training	Passing instructions to new workers, training based on safety plans, training videos.
Safeguards	Hand rails, safety signals, safety nets, fire extinguishers.
PPE	Hard hats, safety shoes, harnesses, hearing protection.
Design	Drawings to assemble scaffolds and handrails systems.
Space	Areas for materials storage, released areas in the industrial building.

At the look-ahead planning level, execution methods were discussed, which is of major importance to carry out realistic safety planning. During the empirical study, it gradually became clear that this discussion should be undertaken at the level of operations performed by workers. This was needed because the stakeholders tended to neglect the uncertainty related to methods and assume that teams would know how to carry out the work packages. In an attempt to make this discussion more systematic, some questions were introduced in the meetings, such as: how will workers access the work station? How will safeguards be installed? Where will body harnesses be attached?

However, the execution methods are unlikely to be thoroughly defined at this level, due to the high uncertainty that still exist. Usually, two or three potentially safe alternatives were considered and the final decision was made during short-term meetings. On site testing of alternatives was sometimes used to provide additional information for decision making.

INTEGRATION TO SHORT-TERM PLANNING

At this level, safety measures were discussed in both weekly and daily planning meetings. The weekly meetings were the most important ones in terms of decision making, since several key stakeholders were involved: the quality manager, the production manager, the safety specialist, client safety and production staff, subcontractor's representatives. Safety and production performance indicators were routinely presented and discussed in these weekly meetings. In daily meetings, safety and production plans were re-evaluated and the client provided a work permit.

Even if formal daily planning meetings did not exist, it was found that some decisions regarding safeguards planning should be made on a daily basis. This was the case, for instance, of the selection of anchorage points for body harnesses during the replacement change of the 300 m length steel mill roof. Such anchorage points had to be daily relocated, according to the crew work pace and restrictions of the facility.

Short-term planning also provided an opportunity to apply one of the core techniques of the Last Planner method, shielding production. Such technique establishes that a work package must only be assigned if five quality requirements have been fulfilled: definition, soundness, sequence, size and learning (Ballard 2000). In this study, safety was considered as part of the soundness requirement.

SAFETY CONTROL

Percentage of safe work packages (PSW)

The main performance indicator used to evaluate safety effectiveness is fairly similar to PPC (Percentage of Plans Completed). It is called PSW (Percentage of Safe Work Packages), indicating the percentage of work packages that are safely carried out. A work package is considered to be safe when all planned preventive measures have been implemented and when no accident, near miss or other unforeseen safety event has happened. In fact, the assessment consists of checking the written safety plans against the actual work being carried out. This establishes a clear link between safety planning and safety control. The formulae used to calculate PSW is presented below:

$$PSW = \frac{\sum \text{number of work packages safely carried out}}{\sum \text{total number of work packages}} \qquad 4.1$$

It must be also emphasized that a work package will be only considered as safe after it has been completed. By definition, accidents are unplanned and uncertain events. Then, there is no total assurance that accidents will not happen, even though all planned safety measures have been implemented. Of course, once plans are followed, the likelihood of accidents to take place tends to decrease. The effectiveness of safety measures depends on the quality of the safety plan, and also on the quality of its implementation.

Figure 1 schematically presents the form used to collect data for calculating PSW in the empirical study. Similarly to the Last Planner Method, the reasons for not following the plans are identified - a checklist is used to categorize them.

Gang	Work package	PHA nº	Safe? Yes	Safe? No	Problem
BSF	Walls from column 25 to 28	PHA 2	X		
SH	Change roof from column 5 to 7	PHA 5		X	Body harness badly tied
	Plans not clearly associated to work packages				
BSF	Common circulation areas	PHA 8	X		
BSF	Center of formwork	PHA 6	X		

Figure 1: Example of form used to collect data for calculating PSW.

This indicator is more effective when it is monitored on a daily basis. Although it is similar to PPC, there are some important differences between that indicator and PSW. Firstly, PSW data collection is more difficult, once some problems can be only identified through careful observation of site activities. Secondly, PSW calculation takes into account activities that are carried out even if they have not been identified in production plans. Moreover, work packages that have not been initiated are not considered in PSW calculation, except if the cause for not carrying it out was the lack of safety. The main steps for collecting data related to PSW are presented below:

- identify the work packages scheduled in production plans. Write down these work packages in the first section of the PSW form;
- in the second section of the same form, list the plans not clearly associated to work packages. During data collection, only those items that have any related activity taking place will be evaluated;
- walk on site and identify where each work package is being carried out. Observe how the activity is being performed and check whether the safety measures listed in the respective PHA are being implemented. The observer must also pay attention to identify any other safety related event not specified in the PHA (for instance, a risk not identified in the PHA). The length of time dedicated to each observation varies according to a number of factors, such as the size of the crew, the complexity of the task and the environmental conditions. In the empirical study, the typical period of time dedicated to observe each work package was around fifteen minutes;
- once an activity not scheduled in the production plans is observed, it should be regarded as a new work package and included in the form. If there is a PHA for this activity, this is the basis to evaluate whether the work package was safe or not;
- when finishing the observations, calculate the daily PSW and analyze the causes for not following safety plans. The completion of the form should only be made at the end of the work day, since other safety failures can be detected.

Other control measures

Besides PSW, other performance indicators were also monitored. Some of them were related to the impact of the lack of safety, such as the number of accidents and delays that resulted from work stoppages caused by safety failures. However, in this research project emphasis was given to controls that had a preventive character. In this respect, two indicators were proposed: (a) the degree of compliance to NR-18, evaluated through a checklist; and (b) a training indicator, calculated through the ratio between man-hours of training and total man-hours. The documentation and investigation of all near misses was another important preventive measure. Near misses were reported by safety specialists and by PSW observers. Ideally, workers should also report such events - this could be achieved by training them to report near misses or unsafe conditions.

The results of all performance indicators were presented in a report, which was discussed in a monthly evaluation meeting. Four of these meetings took place during the study, involving a company director, the production manager, the safety specialist, the quality manager, an outside safety expert and a member of the research team. As the main result of each meeting, an action plan including both preventive and corrective safety measures was produced.

WORKERS PARTICIPATION

The SPC model proposes a cycle of risk identification and control based on workers perceptions, as illustrated in figure 2.

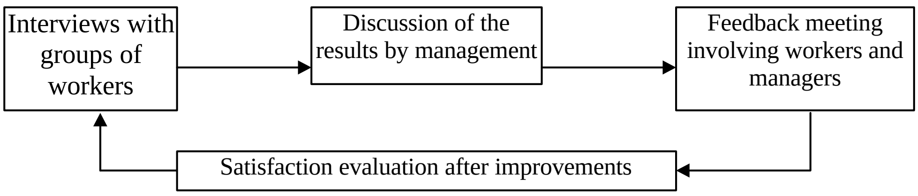

Figure 2: Risk identification and control cycle based on workers perceptions.

The **first stage** involves interviews with small groups of workers. The interviews are divided into two stages: (a) an open section, in which workers are encouraged to talk not only about the tasks performed by them, but mainly about both good and bad aspects of their work, and (b) an induced section in which workers are asked to talk about predefined issues. In the latter section a checklist is used, including the following topics: manual material handling, awkward postures, PPE, workload, relationship with colleagues and managers, food, tools, the most difficult tasks, knowledge on the environmental risks, emergency procedures and temporary facilities. When a problem is reported, workers are asked to suggest ways to solve it.

The main objectives of the interviews were to identify new risks, and to evaluate the effectiveness of existing controls. It must be pointed out that, through the interviews, workers are prone to point out risks that are related to organizational issues, such as job enrichment, rhythm or workload. According to Hendrick and Kleiner (2001), such variables have a strong influence on safety, health and productivity performance.

The **second stage** consists of discussing the results of the interviews in a meeting involving production managers and a company director. In this meeting the first draft of an action plan aiming to solve the problems reported by the workers is established. The **third stage** consists of a meeting involving both workers and management, in which the action plan is presented by the management. A justification is presented by the management if any of the demands by the workers have not been dealt with. The meeting is also another opportunity to report both new problems and suggestions and to solve communication gaps between managers and operatives. Finally, the **fourth stage** aims to evaluate workers satisfaction after the improvements have (or have not) taken place. This evaluation is carried out in another group interview, in which new risks can be identified and controls are re-evaluated. No strict interval between interviews has been proposed in this study. However, new interviews should be carried out when a substantial number of new teams come into the site.

Two risk identification and control cycles took place during the empirical study. The first round of interviews was carried out approximately three weeks after starting the work on site, when workers were already fairly familiarised with their work environment. The second round happened forty days after the first one. At that time, a team of painters started to work on site, as well as other bricklayers had been hired. In addition, some of the suggestions given at the first round had already been implemented. The interviews involved groups of eight workers, on average, and all discussions were recorded.

MAIN EMPIRICAL STUDY RESULTS

One accident with work day losses and eleven near misses were registered. Moreover, there were three situations in which tasks did not take place due to safety planning failures. One of these situations illustrates the major importance of safety constraint analyses: crane maintenance personnel could not come into the steel mill when that machine broke down because they had not attended the safety training program provided by the client. Since this training was provided only on Mondays, the maintenance personnel had to wait for a few days before coming into the steel mill.

The PSW indicator was collected in thirty-two working days during a period of four months. This sample corresponded to 40.5 % of the total number of working days in that period. Such data was collected by two researchers, who spent between one and two hours a day in this activity. The decision was made not to assign this task to the safety specialist in the research project. His observation could be biased since he had been working full time in the site and would be evaluating his own work. Figure 3 compares the evolution of PSW and PPC

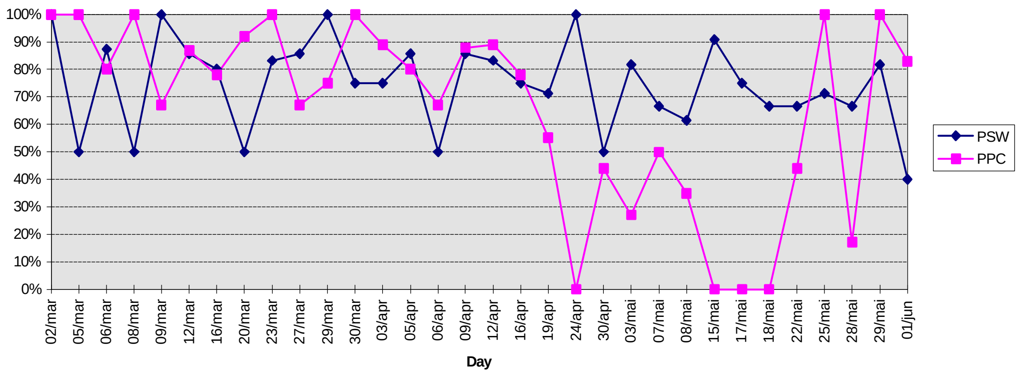

Figure 3: PSW and PPC results.

PSW was on average 74.8 % (S.D. = 16.5 %), while PPC was on average 65.4 % (S.D. = 33.8 %). Although PSW and PPC results had been similar only in five days, at these occasions they were always above of 75 %. This indicates the feasibility to achieve good simultaneous performance both in safety and production planning. In fact, a study carried out by Hinze and Parker (1978) found that safety and productivity were not in conflict, but appeared to be dependent on each other. However, no statistical correlation was found between PSW and PPC in this study (*p-value = 0.7*).

Similarly to the Last Planner Method, the reasons for not following the plans were analysed. Figure 4 indicates that failures in safeguards planning were the main problem in this study.

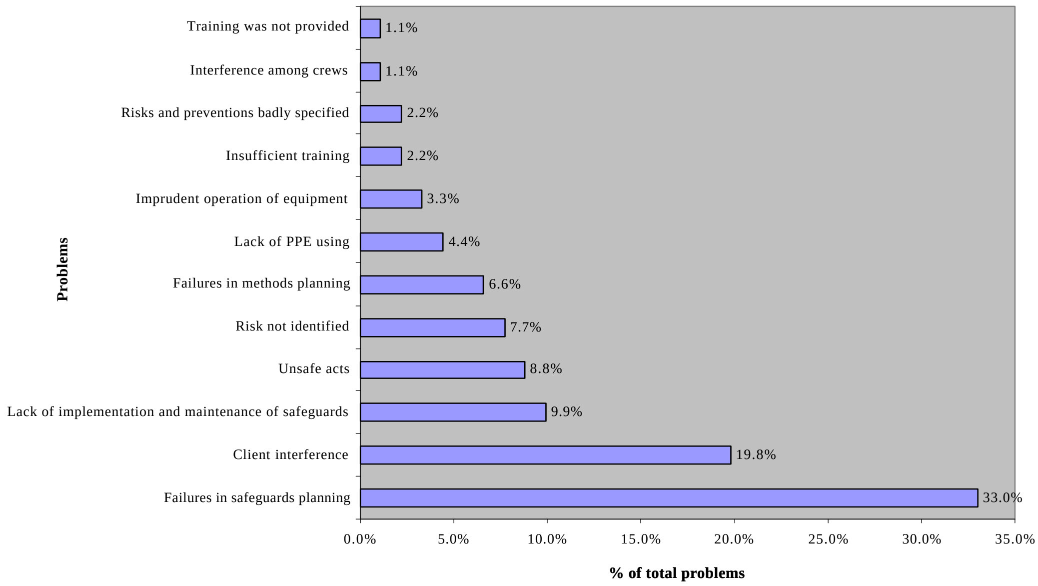

Figure 4: Reasons for not following safety planning.

FRAMEWORK OF THE SPC MODEL

Figure 5 presents the framework of the SPC model proposed as a result of the empirical study. Integrated safety and production planning and control take place in three hierarchical levels. Long-term integrated planning is developed before starting construction, being updated and detailed at both look-ahead and short-term levels of planning. Safety control involves a set of proactive and reactive safety performance indicators. The results are discussed in a monthly meeting in which a company director is involved.

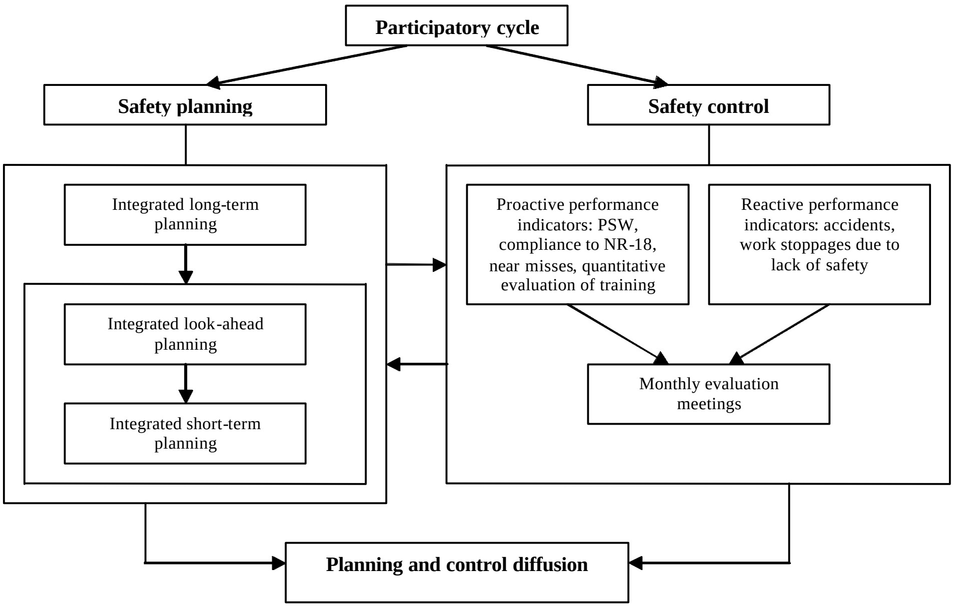

Figure 5: Summary of the SPC model.

Workers` opinions are taken into account through the risk identification and control participatory cycle. Such cycle provides relevant information for safety planning and control, since new risks are identified and the effectiveness of existing controls is evaluated. Safety planning diffusion is achieved mostly by training workers on safety plans before they start carrying out their tasks. In addition to the monthly evaluation meetings, safety performance indicators are also disseminated in weekly planning meetings. This information should be also posted on bulletin boards all over the site.

CONCLUSIONS

This paper presented a safety planning and control model (SPC) which was developed through an empirical study, carried out in the refurbishment of an industrial building. The results indicated that several concepts and methods successfully used in production planning and control, such as constraints analysis, shielding production and analysis of causes for not following the plans, can be easily extended to safety management.

Core requirements of planning and control systems were applied to safety management. Thus, a hierarchical decision-making process on safety measures was established. The Preliminary Hazard Analysis (PHA) technique was used for producing long-term safety plans, being continuously updated and detailed through the integration of safety into look-ahead and short-term planning levels. Safety planning and control was systematic and continuously applied during the whole project. Several stakeholders participated in safety planning and control, including the client, managers, subcontractors and, to some extent, the workforce.

Although it is widely accepted that safety should be integrated virtually into all managerial processes, it seems to be necessary to expand research efforts in this area. The integration of safety into the design phase would be a natural follow up for this research project.

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REFERENCES

Agaj, I. (2000). *Safety in large construction projects.* M.Sc. Dissertation, School of Building Construction, University of Florida, 77 p.

Ballard, G. (2000). *The Last Planner System of Production Control*. PhD thesis. School of Civil Engineering. The University of Birmingham.

Baker, S.; Ponniah, D.; Smith, S. (1999). Risk response techniques employed currently for major projects. *Construction Management and Economics,* v. 17, p. 205-213.

Ciribini, A.; Rigamonti, G. (1999). Time/space chart drawings techniques for the safety management. In: INTERNATIONAL CONFERENCE OF CIB WORKING COMMISSION W99, 2°, 1999, Hawai. *Proceedings...* p. 25-32, Rotterdam: A.A. Balkema.

Dias, L.M.; Fonseca, M.S. (1996). *Plano de segurança e de saúde na construção (Safety and health plan in the construction industry - in Portuguese).* Lisboa: Instituto de Desenvolvimento e Inspecção das Condições de Trabalho.

Eden, C.; Huxham, C. (1996). Action research for management research. *British Journal of Management*, v. 7, p. 75-86.

Hendrick, H.; Kleiner, B. (2001). *Macroergonomics:* an introduction to work system design. Santa Monica: Human Factors and Ergonomics Society.

Hinze, J. (1998). *Construction Planning and Scheduling*. Upper Saddle River: Prentice-Hall, 326 p.

Hinze, J.; Parker, H. (1978). Safety: productivity and job pressures. *Journal of the Construction Division,* v.104, n. 1, p. 27-34.

Kartam, N. (1997). Integrating safety and health performance into construction CPM. *Journal of Construction Engineering and Management*, v. 123, n. 2, p. 121-126.

Kolluru, R.; Bartell, S.; Pitblado, R.; Stricoff, R. (1996). *Risk assessment and management handbook.* Mc Graw Hill.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction.* VTT, Technical Research Centre of Finland, 258 p.

Laufer, A.; Tucker, R.; Shapira, A.; Shenhar, A. (1994). The multiplicity concept in construction project planning. *Construction Management and Economics,* London, v.12, n. 1, p. 53-65.

Laufer, A.; Tucker, R. L. (1987). Is construction planning really doing its job ? A critical examination of focus, role and process. *Construction Management and Economics*, London, n. 5, p. 243-266.

Liska, R.W. et al. (1993). *Zero accident techniques.* Austin: The Construction Industry Institute.

McCollum, D. (1995). *Construction safety planning*. New York: Van Nostrand Reinhold, 285 p.

McKenezie, J.; Gibb, A.; Bouchlaghem, M. (2000) Communication: the key to designing safely. In: DESIGNING FOR SAFETY AND HEALTH CONFERENCE, London. *Proceedings*... www.eci-online.org

Saurin, T.A.; Formoso, C.T.; Guimarães, L.B. (2001) Integrating safety into production planning and control process: an exploratory study. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP OF LEAN CONSTRUCTION, 9°, Singapore. *Proceedings*..., National University of Singapore.

Suraji, A.; Duff, R.; Peckitt, S. (2001). Development of causal model of construction accident causation. *Journal of Construction Engineering and Management*, v. 127, n. 4, p. 337-344.

Tah, J. (1997). Towards a qualitative risk assessment framework for construction projects. In: IPMA SYMPOSIUM ON PROJECT MANAGEMENT, 1997, Helsinki. *Proceedings*... p. 265-274, London: E&FN SPON.