SAFETY-I AND SAFETY-II: OPPORTUNITIES FOR AN INTEGRATED APPROACH IN THE CONSTRUCTION INDUSTRY

Guillermina Andrea Peñaloza [1]
Kinga Wasilkiewicz [2]
Tarcisio Abreu Saurin [1]
Ivonne Andrade Herrera [3]
Carlos Torres Formoso [1]
[1)] *Universidade Federal do Rio Grande do Sul, Brazil*
[2)] *Norwegian University of Science and Technology, Norway*
[3)] *SINTEF, Norway*

Abstract
Construction projects are known for their complexity characteristics, such as a large number of stakeholders, uncertainty, and a dynamic work environment. These characteristics imply that different approaches for safety management can be useful under different circumstances. For example, low severity occupational accidents are fairly common in most construction sites, and therefore these events offer useful learning opportunities. In turn, resilience across managerial and operational levels is probably ubiquitous in construction sites, regardless of being taken for granted and neglected as a source of learning. Therefore, there is an opportunity for the joint use of how Safety-I and Safety-II in construction, giving rise to more effective safety management. This paper explores how Safety-I and Safety-II can be jointly adopted in construction. The discussion is based on two case studies, one from Brazil and another from Norway, in which two safety practices – safety planning and event reporting - were analysed from the perspectives of Safety-I and Safety-II. We conclude that these two perspectives can be integrated into established practices allowing organisation to learn from accidents, incidents as well as from everyday operations.

Keywords: Safety-I, Safety-II, construction industry

1. INTRODUCTION

Safety-I and Safety-II are two perspective aimed at improving the management of safety, although from different viewpoints. While Safety-I is established with a long history and is based on understanding of risk through failure and past events, Safety-II has emerged in recent years as an approach for understanding what goes well, and how safety and risk arise from everyday work [1, 2].The need for Safety-II arises from the growing complexity of socio-

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technical systems and the plateau of accident rates in some industries, which poses less opportunities for learning from unwanted events.

This paper explores Safety-I and Safety-II in the construction industry, which has characteristics of complex socio-technical systems [3, 4], such as a large number of stakeholders, sub-systems, regulations, and procurement approaches [5,6]. Therefore, by additionally focusing on what goes well, the construction industry can benefit from the Safety-II perspective by exploring the resilience potentials at the organisational level However, even though the two perspectives are thought to be complementary [2], there is little practical guidance on how this can be achieved and whether this already occurs in practice to some extent [7].

In Norway the construction industry is one of the industries on mainland Norway with the highest number of fatalities and serious accidents [8]. In 2017, the number of reported work accidents per 1000 employees was 5.5 [9]. Similarly, in Brazil, the construction industry is one of the sectors which shows the highest number of work accidents. The statistics indicate that in 2017 the work accidents rate per 1000 employees was 5.9 [10]. The objective of this paper is to explore how Safety-I and Safety-II can be jointly adopted in construction. To understand how the Safety-I and Safety-II approaches are explicitly or implicitly implemented in the construction industry, we have gathered data from one project in Brazil and another in Norway. Two safety practices common to both projects are discussed: (i) safety planning, and (ii) event reporting. These practices are analysed based on a Safety-I and Safety-II criteria, setting a basis for the identification of opportunities for integrating both approaches.

2. BACKGROUND

2.1. Safety-I and Safety-II

The Safety-I approach is broadly used in safety management. In this approach, organizations focus on risk management and accident analysis to address failures, incidents and accidents. As a result, the knowledge gathered from these failure-focused events becomes the learning basis for the prevention of future situations [11,12]. The fundamental idea of this approach is to avoid things from going wrong through the creation of barriers, procedures and by standardizing work processes [2, 13].

In a work environment characterised by increased complexity, the unexpected events, hidden interdependencies and cascade effects may affect safety performance leading to changes in the nature of accidents [5,6]. Thus, Safety II has been promoted as a complementary approach to Safety I for safety management. It emphasizes understanding and learning from successes in everyday work. The key idea is to study why things go right in order maximize the number of acceptable outcomes under varying conditions. [2, 12].

Different criteria to characterize each approach have been proposed in the literature [11, 13, 14, 15, 16, 17]. Table 1 compares the Safety-I and Safety-II approaches inspired by the criteria from the literature.

Table 1: Criteria for comparing Safety-I and Safety-II

	Safety-I	Safety-II
Understanding of safety	Reducing what goes wrong	Increasing what goes right
Learning basis	Unwanted events	Everyday work
Practices and tools	Reactive and proactive in terms of addressing failures, accidents and unacceptable risks	Reactive and proactive in terms of understanding successes and surprises in everyday work
Strategy to cope with performance variability	Harm should be prevented, e.g. by barriers, standardized processes, compliance with procedures	Variability needs to be monitored and managed, e.g. reconciling work-as-imagined and work-as-done

3. RESEARCH METHOD

Multiple sources of evidence have been used in this investigation, including analysis of documents, semi structured interviews and direct observations from one construction site in Brazil and one construction site in Norway. The main characteristics of these projects are presented in Table 2. This data was originally gathered for the purpose of other research project, an investigation of safety performance measurement systems (in Brazil and in Norway). In both construction sites, an overall description of the safety management systems was produced.

Table 2: Main characteristics of the studied construction projects

Characteristics		Construction projects	
		Norway	Brazil
Project	Type	Twelve residential buildings with different typologies	Ten residential buildings with same typology
	Main construction technologies	Prefabricated steel roofs and walls, and precast concrete columns	Cast in place concrete structure. Interior/exterior masonry walls
	Area	35.000 m^2	17.000 m^2
Construction phase being carried out during case study		Concrete and timber structure, finishing, heating, ventilation and air conditioning services	Masonry, hydraulic and electric services

The safety related documents analysed in each construction project included standardized operating procedures, description of performance indicators, checklists and safety reports.

Three semi-structured interviews were conducted in each case study including the site manager and two safety representatives. The interviews were comprised of questions related to Safety-I (e.g. *How does the organization learn from incidents and accidents? For 'lagging' indicators, how long is the typical lag? Is it acceptable?*) and Safety-II (e.g. *Does the organization try to learn from the things that go right in every day work? Does the operational procedures allow workers to adjust their actions as they deem appropriate?*)

About ten hours of direct observations, distributed in five visits, were carried out in each construction project. Direct observations focused on the execution of construction activities as a way to understand the main hazards and preventive measures adopted by the companies, as well as in the planning meetings related to safety management.

Based on the aforementioned data collection, two safety practices were selected for the analysis: safety planning and event reporting. Data indicated that these two practices were adopted in both countries, allowing for a meaningful comparison.

Qualitative data from all sources were subjected to a content analysis in which excerpts of text were identified from interviews´ transcripts, documents and notes from observations. Data was analysed using the theoretical perspectives of Safety-I and Safety-II, based on the criteria previously described in section 2.2. Thus, the strengths and weaknesses of existing practices were identified from the Safety-I and Safety-II perspectives.

4. DESCRIPTION OF THE PRACTICES

4.1. Safety planning

In the Norwegian project, the planning system consists of six levels that range from master schedule, phase schedule, lookahead schedule, weekly work plan, team plan and last-check out plan. Each level integrates different roles such as project manager, site manager, safety coordinator, foreman, team supervisors and operational workers. At each plan level, the risks and hazards of the activities are identified. Also, for some activities the need for Safety Job Analysis (SJA) is defined and developed.

In the Brazilian project, the planning of safety activities is performed by the safety engineer, who works part-time on site and the safety technician (full-time), and is carried out as part of the short-term production planning, which has a weekly planning horizon. This consists of the creation of work packages in which all the activities necessary to execute a construction phase (e.g. painting, roofing, etc.) are defined. Then, the safety planning involves the definition of additional work packages focused on preventive measures and physical barriers such as scaffolding, temporary protections, personal protective equipment, work permits, etc.

4.2. Event reporting

In the Norwegian construction project, event reporting was performed by workers and managers from the company and sub-contractors. The reporting system is a part of the overall safety management system, and the reported events can involve near misses and other unwanted events related to natural environment, quality, and health, safety and work environment.

The reporting mechanisms also allow workers to point out the adopted corrective actions, such as removing an obstacle, speaking to a person or immediately reporting to a manager who has authority to take appropriate actions. The events can be reported by filling out forms in small booklets available for all workers on the site or through a mobile phone app. This app also allows to take a photo and record notes of the even reported. The reports are then collected by the safety coordinator on a daily basis, and included in the “Health, Safety and Environment (HSE) deviation list” that is an input for the production planning meetings. The safety coordinator is the responsible to devise a countermeasure and give feedback to the workers in order to close the report in the system. The HSE deviation list is typically a spreadsheet where all the reports are logged, categorized and actions are decided upon before the report is closed.

In the case of the Brazilian construction project, there was no formal reporting system. Workers used to voluntarily report situations and concerns to the safety technicians and also during the weekly safety meetings in which the safety engineer, safety technician and all operational workers participate. However, these meetings focused only on failures, errors, and non-compliance with standards and regulations. An improvement opportunity suggested by the researchers in this construction project was to use at least ten minutes of these meeting to discuss "successful events" (things that go right). This new practice consists of displaying an illustrative poster with photos and notes highlighting the performance of the workers at the construction site, for example, the correct use of equipment and materials as well as the alternative solutions devised by experienced workers in order to cope with everyday problems (Figure 1a). In addition, workers are encouraged to share their experiences and concerns about events which they observed during the week. Events and conditions reported are classified by workers using a colour scheme, where green is a desirable/successful situation, blue is an intermediate situation, and red is an undesirable situation which offers room for improvement (Figure 1b). Then, the safety engineer collects and disseminates this data in the managerial meetings in order to decide the corrective actions.

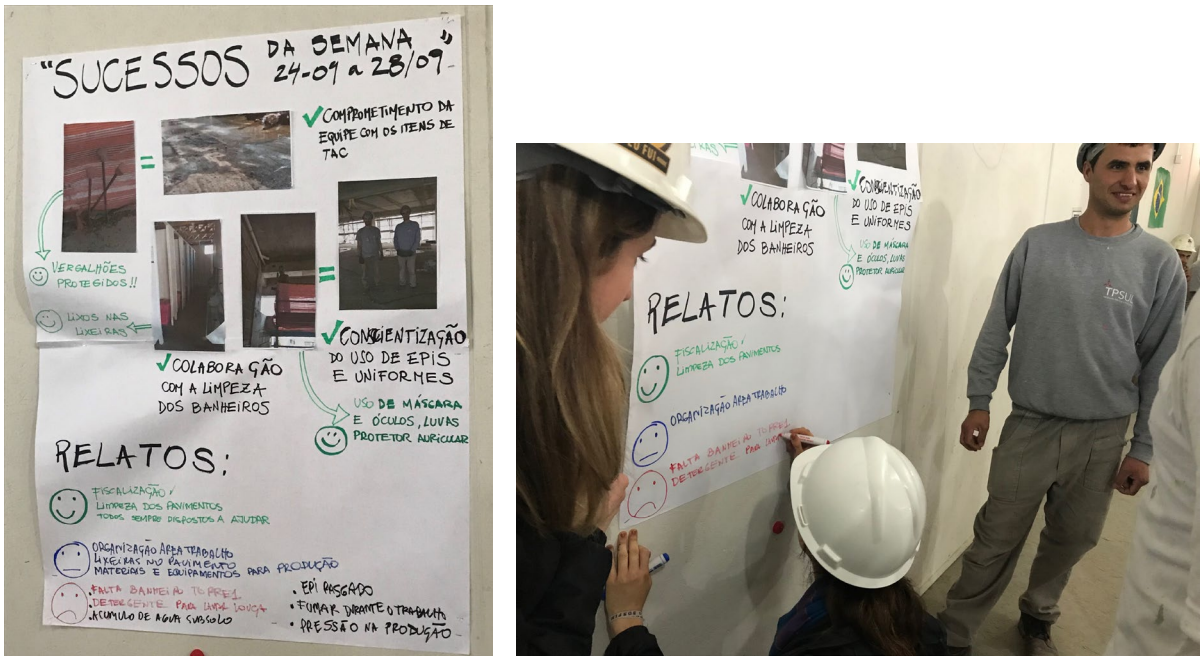

Figure 1: a) successful events poster; b) classification of the nature of the reported event or condition

5. RESULTS

5.1. Safety planning

In the Norwegian and Brazilian project, Safety-I and Safety-II perspectives are implicitly integrated. From one hand, the planning of safety activities always takes into account the things that went right in previous successful projects, such as the selection of experienced planners and skilled workers, the need for regular and special training according to the nature of the tasks, the choice of reliable and tested tools, equipment and methods that performed efficiently, among others. On the other hand, the safety planners also go through the repository of past unwanted events (e.g. accidents, incidents, technical malfunctions) to visualize the hazards and assess risks as a way to avoid similar occurrences.

Although both construction projects learn from failure-focused events they employ different sources to gather the information, such as accidents and events report databases in the case of Norway and accidents investigations and labour inspection reports in the Brazilian project.

In Norway the master and phase schedule are performed before the start of the project by the project and site managers. At this planning level, only the Safety-I perspective is taken into account since the identification of hazards and the development of risk assessments to each construction phase are based on past accidents and reported unwanted events. In turn, the short-term planning meetings or "last-check out" meetings are performed at the beginning of the week, involving the site manager, team leaders and front-line workers who analyse the need for SJA when the operation conditions are not as anticipated by planning.

SJA is a tool intended to be used in daily activities when some of the planning assumptions are no longer valid. One example can be a lifting operation which is initially a routine operation, but as the weather conditions may change significantly during the day, the operation must be adapted according to the emergent risks. This can be considered as a Safety-II approach to the extent that an SJA is developed on the spot to account for variability in real-time. Through the SJA the operational workers can adjust the performance of activity to the current conditions.

In the Brazilian project, safety planning is mostly limited only to the physical protections, equipment and work permits that are necessary to avoid the well-known risks that are associated related to past events (e.g. falls from heights, cuts with electric saw, landslide). Based on the production work packages schedule a safety control schedule is performed. Even though the plans are adapted by the project and safety managers according to the current conditions, in this case there is no formalized mechanism for plan adjustments, involving operational workers, as for example the SJA. The practice of monitoring safety work packages blends Safety-I and Safety-II as this involves measuring the number of completed work packages which succeeded, but no further analysis on the reasons behind why things went right is undertaken. Instead, there is a strong focus on the general causes of why some packages failed.

In both projects, the performance variability is constrained by the selection of barriers that range from physical (temporary protections, personal protective equipment) to functional (equipment interlocking, cranes ratio distances), symbolic (warnings of heavy machines traffic or rigorous trainings such as work at heights) and incorporeal (compliance with company own rules and industrial regulations). Another strategy to cope with performance variability is through the standardization of processes such as the employment of modular and prefabricated building systems.

In turn, the variability of performance is also supported in both construction projects by taking advantage of tacit knowledge and diversity of project participants perspectives and skills. This is helpful when solutions for unplanned situations are needed, or alternatives for construction techniques need to be discussed. This is aligned to Safety-II since the improvisations and adaptations performed by experienced workers normally lead to positive outcomes. Table 3 summarizes the analysis of the safety planning in each construction project

Table 4: Analysis of the safety planning in each construction project

	Safety planning	
	Norway	Brazil
Understanding of safety	**S-II** What and why thing go right **S-I** What and why thing go wrong	
Learning basis	**S-I** Use of failure-focused events such as accidents and events report databases	**S-I** Use of failure-focused events such as, accidents investigations and labour inspection reports
Practices and tools	**S-I** Risk assessment per construction phase (phase schedule) **S-II** Decide SJA for operations under varying conditions (look ahead and weekly work planning). Go through risks in everyday operations and develop SJA with front-line workers **S-II** Last check-out planning meeting (plan adaptations individually and team based)	**S-I / S-II** Safety control schedule based on safety work packages (number of work packages safely carried out vs. total number of work packages)
Strategy to cope with performance variability	**S-I** Selection of barriers, standardized processes, compliance with procedures, rigorous training **S-II** Taking advantage of tacit knowledge and diversity of project participants perspectives and skills	

Note: **S-I:** Safety-I; **S-II:** Safety-II

5.2 Event reporting

In the Norwegian study, event reporting is mainly focused on negative events (e.g. accidents) and deviations (e.g. near misses) which are reported through booklet and app. However, some good practices are also reported by the employee responsible for the weekly safety inspection (safety coordinator, one safety representative, one team leader one operational worker) during the observations. For example, the tidiness of work stations or the proper use of scaffolds.

In the Brazilian project, as previously mentioned, there was no formal event reporting system. The voluntary reports and discussions in weekly safety meetings were strongly focused on what went wrong. An integration of Safety-II was incipient through the previously mentioned implementation of "successful event" discussions in the safety meetings. Since this implied a new practice with a different perspective of understanding safety, the safety engineer and safety technician argue that it was challenging to gather examples of "successful event" that can illustrate situations beyond the well know best practices, e.g. the correct use of personal protective equipment or the tidiness of the common facilities and hygiene.

In the Norwegian project, the information from the events reported is used for learning from both the failures (e.g. accidents and injuries) that triggered the event and by the immediate corrective measures. This point is illustrated by a report by one of the workers: *"I was going down from the ramp, and the stairs (which consisted of pallets) were not laying straight. The pallet slid and I fell on the ground. I hit my side and my head".* In this case the immediate action

described by the worker was *"I fixed the pallets so they were laying properly"*. The feedback from the HSE-coordinator for this report back to the worker was appreciation of fixing the ramp *"Great that you fixed the pallets properly"*. The report mechanisms (booklet and app) also encourage to report near misses and deviations. This is why the events reporting system could be considered both Safety-I and Safety-II. However, the data are only analysed through Safety-I lenses looking at what went wrong and trying to avoid it from happening again, although the collected data could offer insights into instances that achieved the intended outcome. In the Brazilian project, the learning through reported events takes place in the weekly safety meeting for the operational workers, while for top level managers this learning process occur in a separate meeting. In both projects, the examination of events reported look mostly for proximal causes neglecting the role played by resilience.

In Norwegian project, one strategy to cope with performance variability is through the use of a reactive indicator, referred to as "number of deviations reported". However, another strategy is the effective implementation of corrective actions. These can be performed in different ways. For example, they can be carried out by the same worker who did the report, as in the case of the pallets. As such, the implementation of corrective actions is decentralized, since the organization recognizes the experience and abilities of their own company workers to implement effective corrective actions. In other situations, when involving outsourced workers, an employee with authority (e.g. team leader, safety coordinator, site manager) is requested to take actions.

In the Brazilian project, the corrective actions are centralized in a higher organizational level which is considered as a Safety-I approach. The safety and project managers are the main responsible to devise and implement these. Table 4 summarizes the analysis of the events reporting in each construction project.

Table 5: Analysis of the events reporting in each construction project

	Event reporting	
	Norway	Brazil
Understanding of safety	**S-II** What and why thing go right **S-I** What and why thing go wrong	
Learning basis	**S-I** / **S-II** Database of reported events consisting in failures (accidents and injuries) and deviations (near misses)	**S-I** / **S-II** Reported events from the weekly safety meeting
Practices and tools	**S-I** Examination of events look mostly for proximal causes. Role played by resilience is neglected.	
Strategy to cope with performance variability	**S-I** number of deviations reported **S- II** monitoring of events and implementation of corrective actions performed by experienced workers as well as by employees with formal authority	**S-I** corrective actions centralized in safety and project managers

Note: **S-I:** Safety-I; **S-II:** Safety-II

6. DISCUSSION

The formal activities and tools involved in the practices analyzed in this study, such as risk analysis, work procedures and most of the events used as a basis for reporting and learning, are based on a Safety-I approach. However, the daily practices observed in those two projects have, in many ways, features of Safety-II, especially at the operational level, as the workers constantly adapt their performance to the current conditions in face of, for example, limited resources and information as well as the opportunities that arise from knowledge transfer between experienced and novice workers as well as between different organizational levels. This very often leads to gaps between work-as-imagined (WAI) and work-as-done (WAD). In the construction industry such a gap can contribute to "making do" waste, which occurs when *a task is started without all its inputs or the execution of a task is continued although the availability of at least one input has ceased* [18]. This leads to improvisations and reworks which can have an impact on safety performance. Therefore, the integration between Safety-I and Safety-II becomes essential.

In the exploratory case studies, some examples of integration between both safety approaches were found. For example, during safety planning the categories of practices such as, the "understanding of safety", the "practices and tools" and the "strategy to cope with performance variability" shows to some extent the use of both Safety-I and Safety-II, while the "learning basis" category is focused only on Safety-I. However, the approaches seem to be used at different project stages and through different organizational levels, not fully exploring the synergies between them. For instance, in the Norwegian project the risk assessments in earlier stages can benefit from the experience of the operational workers especially for those critical operations in which resilience is required. Consequently, this feedback from the things that go right could be used as a basis for learning during safety planning. In the Brazilian project, observations in real time of the safety work packages could reveal aspects of variability which could be useful to reduce the uncertainty in safety planning.

In turn, in the event reporting system, the Safety-II approach could be formalized through the systematization of good practice and successful events in a database or app, similar to the collection of data focused on failures and deviations.

There is a further potential to integrate the two approaches in the construction industry by designing more flexible plans and procedures which take into account for the variability of everyday work and the tacit knowledge of the experienced project participants. Anyway, there will always be a trade-off between the use of these approaches, meaning that not in all situations Safety-I and Safety-II should be jointly used. For example, the Safety-I approach seems more adequate for activities performed in regular conditions in which a high compliance with procedures and plans is possible and sufficient to achieve the desired safety performance. In turn, for activities performed under varying conditions the Safety-II approach is recommended since it enables the identification of the necessary adjustments needed to cope with the changing conditions and learn also from what goes right and not only from what goes wrong.

7. CONCLUSIONS AND FURTHER RESEARCH

Two safety practices, common to one project in Brazil and one in Norway have been analyzed from a Safety-I and Safety-II approach. The results show that, although the Safety-I is adopted

through methods, practices and tools in both projects, some aspects of Safety-II are also present but in a less formalized way. There is potential to integrate Safety-II in current safety management, through for example the use of observations, discussions and storytelling.

As the analysis was limited to two safety practices and the examples are not exhaustive, some proposals for future studies are suggested: (i) to explore other safety practices according to the same analytical approach adopted in this study; (ii) to explore how informal planning occurs in construction sites, (iii) to explore the implications of Safety-II to the design and operation of the event reporting systems, in terms of the nature and frequency of reported events as well as the opportunities for integrate reports of successful processes; and (iv) to explore how safety and production planning should place an emphasis on the design and/or creation of slack (e.g. multifunctional employees, redundant piece of equipment, time margins for equipment maintenance, help chain, etc.) instead of only adding more barriers.

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