

COB-2023- 0483
RISK ANALYSIS IN BELT CONVEYOR PROJECTS

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Abstract. Mining is one of the main Brazilian economic sources. According to data from Brazilian Institute of Mining in 2020 the participation of the mineral sector in Brazil's GDP was approximately 4% (IBRAM, 2020). The mining sector is technological, competitive, and demands efficiency and quality throughout the production process. Belt conveyors are one of the main transportation methods in the Mining industry and their design always consider the granulometry, heterogeneity and humidity of the mineral, the characteristics of the mine project, and the expected productivity. Although Mining industry represents a significant portion of the Brazilian economy, the occupational risks associated with this activity are indisputable. The rate of death, injury, and illness among the world's miners remain high and mining remains a hazardous occupation in terms of the number of people exposed to risk. This paper demonstrates the importance of the Safety Risk Analysis in belt conveyor projects. Brainstorming technique with 27 volunteers that have at least 20 years of experience in belt conveyor projects together with equipment drawings analysis were considered. As a result of the survey, a risk analysis was carried out with focus on the operator safety based on NR-12, the local regulatory standard for safety work with machinery and equipment, demonstrating the importance of analysis focused on safety in the design phase.

Keywords: Belt Conveyor, Risk Analysis, Mineral Conveying, Brainstorming

1. INTRODUCTION

Mining is one of the main Brazilian economic sources. In 2020 the participation of the mineral sector in Brazil's GDP was approximately 4%, according to data from the Brazilian Institute of Mining in 2020.

As has been reported in several studies carried out by the Brazilian Mining Institute for the first half of 2020, there are several investment projects announced in Brazil, all of which adhere to international practices of operational and occupational safety and sustainability. It can be noted that the total number of announced projects has continuously increased. The investment expectation is US\$ 32.5 billion, to be applied between 2020 and 2024 (Brazilian Institute of Mining, 2020).

Although the activity represents a significant portion of the national economy, the environmental and occupational risks associated with this process are indisputable. Despite considerable efforts in many countries, death, injury, and disease rates among the world's miners remain high and mining remains the most dangerous occupation in terms of the number of people exposed to risk (ILO, 2019).

Risk can be understood as the association between the probability of occurrence of an event and the severity of its consequences. Risk management and analysis methodologies seek to identify potential hazards and categorize risks in order to help prevent and mitigate damage.

In 2014, Regulatory Norm NR 22, Ordinance No. 732 of the Ministry of Labor and Employment, made it mandatory for the mining company to prepare and implement the Risk Management Program (PGR). Some of the minimum items that must be included in the PGR are: physical, chemical and biological risks; explosive atmospheres; analysis of work accidents; ergonomics; risks of working at heights, in depth and in confined spaces; risks from the use of electricity, machines, equipment, vehicles and manual work; mandatory personal protective equipment and emergency plan. According to Candian (2018), although there has been a significant reduction in the rate of injuries and accidents in Brazilian mining in recent years, the number and degree of severity are still high by industrial standards.

Risk management is understood as a set of disciplines that architect the adoption of a system of procedural, structural, methodological and policy elements, enabling better discernment of acceptable risk limits. To this end, as defined by Hope (2002), a manifestation of risk consists of uncertainty about the occurrence or not of a loss, and the way to control these uncertainties is by resorting to their management.

For Badri (2015), the risk management process is about preventing problems or unwanted results, where for the most part, risks are evaluated in terms of probability of occurrence and impact. And in a progressive way, the risk management process must be exhaustively improved, monitored and constantly analyzed, in view of possible changes in relation to risks in all their aspects.

The first way to prevent failures and accidents is to focus on the quality of the project, taking into account aspects of maintenance, construction and operation of the plant, so that operational deviations are within acceptable limits and are not frequent to the point of being outside of specifications (KUMAMOTO; HENLEY, 1996).

Risk analysis in the design phase of a belt conveyors is of great importance as it reduces costs, mitigates design errors, and reduces the risk of accidents. It can be done from the input of certain specifications of the land soil, equipment and material to be transported. For the risk analysis of a specific belt conveyor, equipment drawings, brainstorming meetings and analysis of review markups were used in conjunction with the current regulations in the country where the project was implemented.

2. LITERATURE REVIEW

2.1 Risk management

All activities (operations, processes, and projects) of an organization involve risks that need to be managed. According to ABNT ISO Guide 73 (ABNT, 2009), which presents a vocabulary related to risk management, a risk can be considered as the effect of uncertainty on the objectives, so that this effect is a deviation from what is expected, and may address, create or result in opportunities or threats. Thus, the risk management process takes into account the uncertainties and the possibilities of future circumstances or events, whether intentional or no, and its effects on the established objectives (ABNT, 2012). This process has the purpose of creating and protecting value, in a way that seeks to improve the performance, encourage innovation and support the achievement of goals (ABNT, 2018).

Organizations of all types and sizes face influences and factors external and internal that make the achievement of its objectives uncertain (ABNT, 2018). There are several approaches, norms, models and frameworks with consistent and compliant guidelines for organizations to implement processes of effective business risk management (Perera, A. A. S. 2021). Among these structures, we can highlight the ABNT NBR ISO 31000 and the COSO Enterprise framework Risk Management, which are widely used standards in risk management (Priyarsono, DS, 2019). Many authors state that the use of ISO 31000 is a good practice for corporate risk management (Abaoud, Duaa, 2019). Among the advantages of using ISO 31000 as a standard for the risk management process, is the fact that it can be easily integrated with other ISO standards, for example, the quality management ISO 91001 (ABNT, 2015).

In this context, it is also noteworthy that when developing projects of data mining, it is necessary to identify the risks that may impact them. In addition, a description of the consequences of risks and an indication of what actions can be taken to minimize the effects of their occurrences (SPSS Inc, 1999).

Andrade (Andrade, 2017) shows that it is possible to associate the process of data mining, in particular that which follows the Cross Industry reference model Standard Process for Data Mining (CRISP-DM), with the risk management process presented in ISO 31000, because, although each one of them has its particularities and stages, their similarities allow them to happen in a complementary and parallel.

2.2 ABNT NBR ISO 31000

ISO standards have been continually reviewed to ensure that principles and guidelines are relevant and updated to meet the market needs (Perera, A. A. S. 2021). In this sense, the last version of ISO 31000 was published in 2018 (ABNT, 2018), whose risk management process is illustrated in Figure 1.

The risk management process presented in ISO 31000 is composed of the following steps:

- Establishment of scope, context and criteria: aims to customize the risk management process, allowing it to be effective and appropriate to its defined scope; the external and internal contexts; and to defined criteria to assess the significance of each risk and to support the decision-making processes.
- Risk assessment, whose purpose is to support decisions, involving the comparison of risk analysis results with risk criteria established to determine where further action is needed: it is conducted systematically, iteratively and collaboratively, based on the knowledge and views of interested parties; it is step is done through the following sub-steps:
 - Risk identification, which aims to find, recognize and describe risks that can help or hinder an organization from achieving its goals. At this stage, relevant, appropriate and up-to-date information is important.
 - Risk analysis, which focuses on understanding the nature of risks and their characteristics through detailed consideration of uncertainties, sources, consequences, probabilities, events, scenarios and controls, considering their efficiency.
- Risk treatment: has the purpose of selecting and implementing options for addressing risks; in addition to implementation, it is necessary to evaluate the effectiveness of this treatment; also, it decide whether the remaining risk is acceptable; and in case the risk is not acceptable a further treatment shall be performed.
- Communication and consultation: seeks to bring together different areas of specialization for each stage of the risk management process; and provide sufficient information to facilitate risk monitoring and decision-making. It is recommended that this step occurs throughout the process of managing risks, with appropriate external and internal stakeholders.

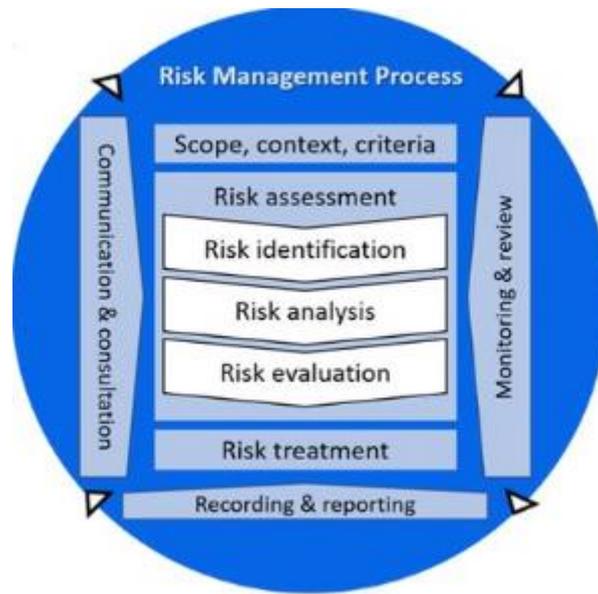


Figure 1 - ISO 31000 risk management process. Source: ABNT, 2018.

- **Monitoring and critical analysis:** aims to ensure and improve the quality and effectiveness of the design, implementation and results of the risk management process. Just like the "Communication and consultation" stage, risk monitoring should be continuous and critical analysis should be periodic at all stages of this process, with planned results and clearly established responsibilities.
- **Registration and reporting:** aims that all stages of the process of managing risks and their outcomes are documented and reported through appropriate mechanisms. This stage is intended to improve the quality of dialogue with the parties stakeholders and support those responsible for the risk management process in taking decision-making and the fulfillment of their responsibilities.

In the activities that make up the risk assessment process, there is a range of tools and techniques that can be used, so ABNT NBR ISO/IEC 31010 (ABNT, 2012) is intended to reflect current good practices in choosing these elements.

2.3 Brainstorming

According to the Brazilian Association of Technical Standards (ABNT, 2012), through Brainstorming it is possible to stimulate and encourage the free flow of conversation between a group of people knowledgeable about a given topic, thus enabling the identification of risks together with their treatment options. This technique is particularly useful when identifying the risks of new technologies, for which the data is not fully known, or innovative solutions to problems are required. Therefore, the results of applying this technique are dependent on the stage of the project in which the risk assessment is being carried out. To enhance the risk assessment process, Brainstorming can be used in conjunction with other techniques and tools, such as root cause analysis (Straub, Jeremy, 2014)

2.4 Belt Conveyor.

According to Eletrobrás et al. (2009), belt conveyors present the widest range of capabilities, versatility, reliability, economy and operation safety.

Belt conveyors, whether fixed or mobile, have low operating costs and transport the most diverse materials, from fines to materials with high granulometry (SACRAMENTO, 2021). Another advantage is that this equipment can be used in the most varied types of land and lengths, and can be open, closed or even enclosed, avoiding air pollution (SACRAMENTO, 2021).

Belt conveyors are composed of a motorized system that moves a belt directed by idlers and pulleys (LOPES, 2010). The mineral is loaded into a chute and then discharged onto the belt conveyor. The mineral moves supported by the belt until the next destination. The belts consist of a top layer, carcass and a bottom layer. Layers are generally constructed of rubber that has the function of covering the carcass and protecting it from the effects of abrasion, impact, cutting, temperature or chemical attack from transported mineral or other adverse conditions (ABNT NBR 6177, 2016). The carcass is the part intended to support the loads of traction, impact and tear resistance, generating bedding, alignment and stretching (ABNT NBR 6177, 2016).

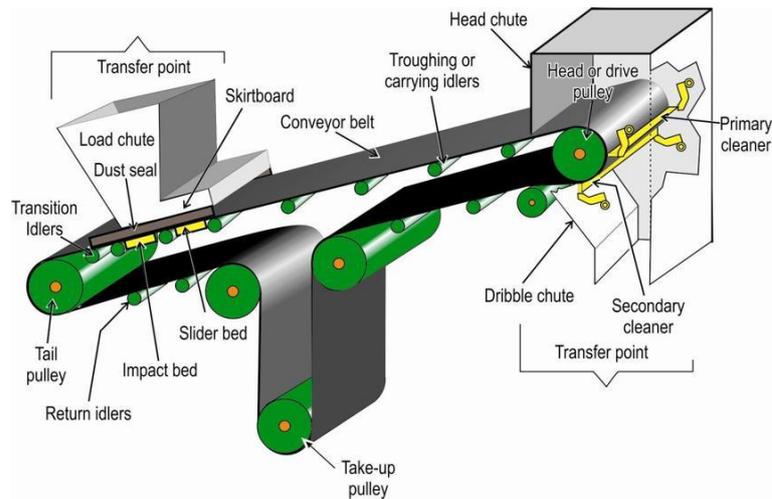


Figure 2 - Belt conveyor terminology (CONBELT, 2019).

This transport system, according to Lopes (2010), is advantageous because it has practically uniform energy demand, reduce operational labor since one or two operators are enough to monitor long stretches of belt in operation (CEMA, 1997 apud LOPES, 2010). In addition, other advantages are the reduction of accident risks due to the smaller number of equipment involved in operation, the non-emission of CO₂ and the lowest operating cost compared to transportation by trucks. (LOPES, 2010). On the other hand, Lopes (2010) states that flexibility is compromised, since the mining fronts must be close to the equipment to enable its use, the granulometry is limited by the system of belts and a higher investment cost is required. According to Chaves (2015), the total costs of transport by belts conveyors are originated by the cost of capital, which represents 94% of the total cost, and operating costs, which represent 6% of the total cost.

2.5 NR12

NR12 (acronym for Regulatory Standard number 12) is a set of safety procedures aimed at the installation, operation and maintenance of machines in work environments in order to guarantee the health and physical integrity of the professionals who will work in them. Some remarkable paragraphs from NR12 are:

- 12.2.2 - The minimum distance between machines, in accordance with their features and applications, must protect the safety of workers during its operation, maintenance, adjustment, cleaning and inspection, and allow the body movement, given the nature of the task.
- 12.2.3 - Areas for circulation and storage of materials, and spaces around machines must be designed, sized and maintained so that the workers and transporters of materials, whether mechanized or manual, move safely.
- 12.5.1 - The danger zones of machines and equipment must have security systems, characterized by fixed guards, mobile guards and interconnected safety devices that safeguard health and safety physical integrity of workers.

3. METHODOLOGY

A belt conveyor already in the executive design phase was analyzed by a team made up of 27 professionals with at least 20 years of experience in industrial projects. All professionals who participated in the survey were volunteers and were aware that the information obtained would be used in this article.

Three meetings were held with the presence of nine participants and a mediator (the author), lasting 40 minutes. The number of participants was defined based on Flick (Flick, 2009), which advocates that the work study group should be comprised of five to nine people. The meeting place had a round table and office chairs.

Flick (Flick, 2009) suggests that the work should be done with unknown people instead of a group of friends or acquaintances, as the number of observations and counterpoints tends to be greater this way. The moderator must guarantee everyone's participation, avoiding favoritism towards certain participants, and must avoid expressing personal opinions so as not to influence the participants' opinions.

When the group of nine participants were ready to enter the room, the door was opened so that everyone could choose their chair. The participant was then faced with a form where they were informed about the anonymity of the survey, in addition to receiving a drawing in A3 format of a belt conveyor with plan and elevation views. The copies were identical. They were then asked to read the term and remain in the room if they agreed.

The main comments were based on NR 12. The participants emphasized that the width for passage and maintenance access in the region shown in figure 2, 603mm, should be wider and suggestions were to expand it to at least 800mm, as recommended by the standard. Figure 4 shows the belt conveyor plan view and the mentioned detail.

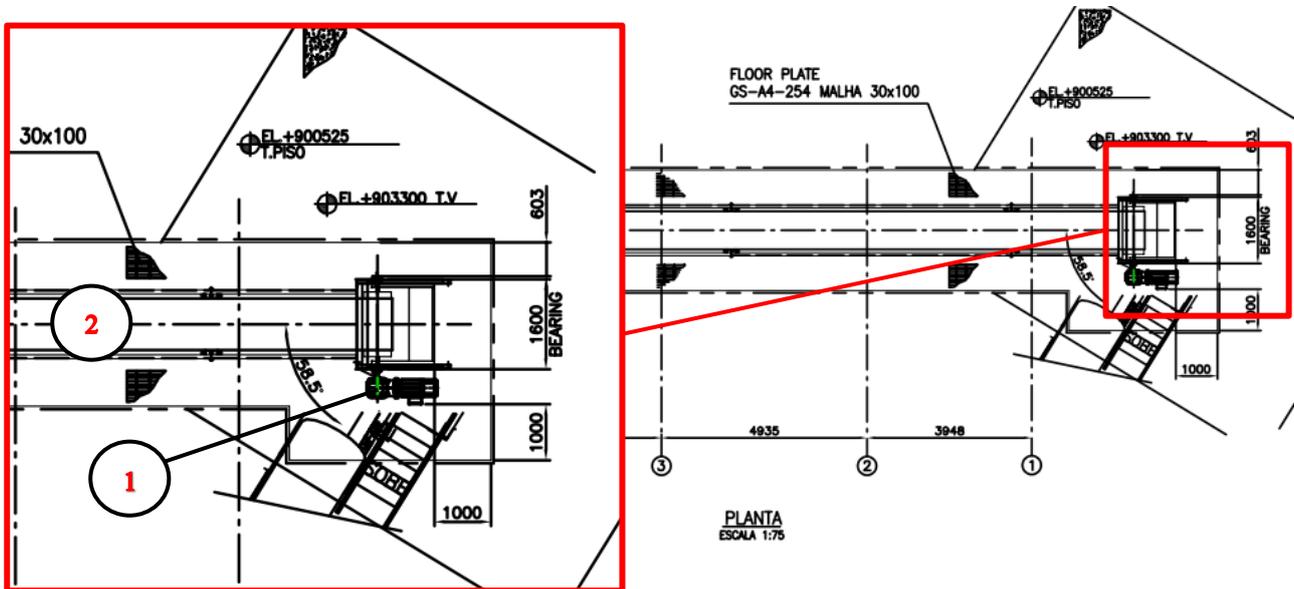


Figure 4- Commented plan view.

The participants also mentioned that as the motor (1) and belt conveyor (2) are not insulated or protected, so the way the project was carried out puts operators at risk, then mobile protection should be added along the conveyor.

Of the 27 participants of the survey, 20 spoke about the protections and the passage area not respecting the standard recommendations in this region of the conveyor and reported difficulties experienced and accidents caused by this type of design error; many of the accidents reported were serious, such as amputation of limbs and death.

Figure 4 shows the staircase (3) to access the conveyor (2), and the existing crusher (4) platforms (5). Due to the position of the access and elevation of the existing platform, the operator can hit his head against the existing crusher platform. As showing in Figure 5, from the third step of the staircase (3) to access the conveyor (2) the available height is 1645mm, putting operators at risk.

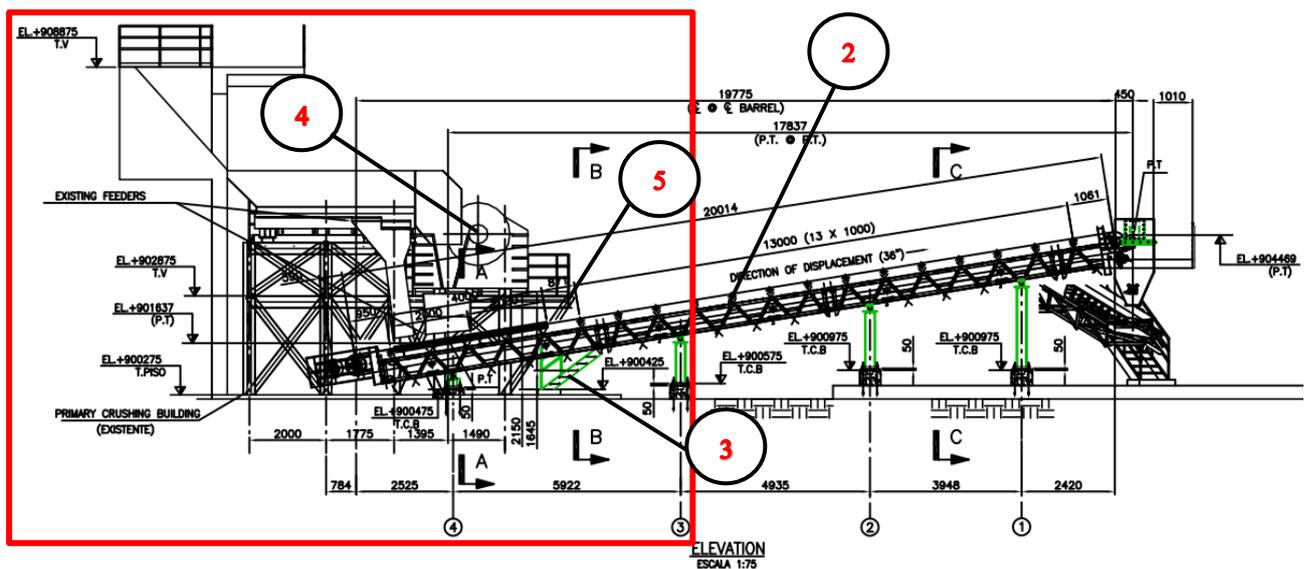


Figure 5 – Survey conveyor: Elevation View

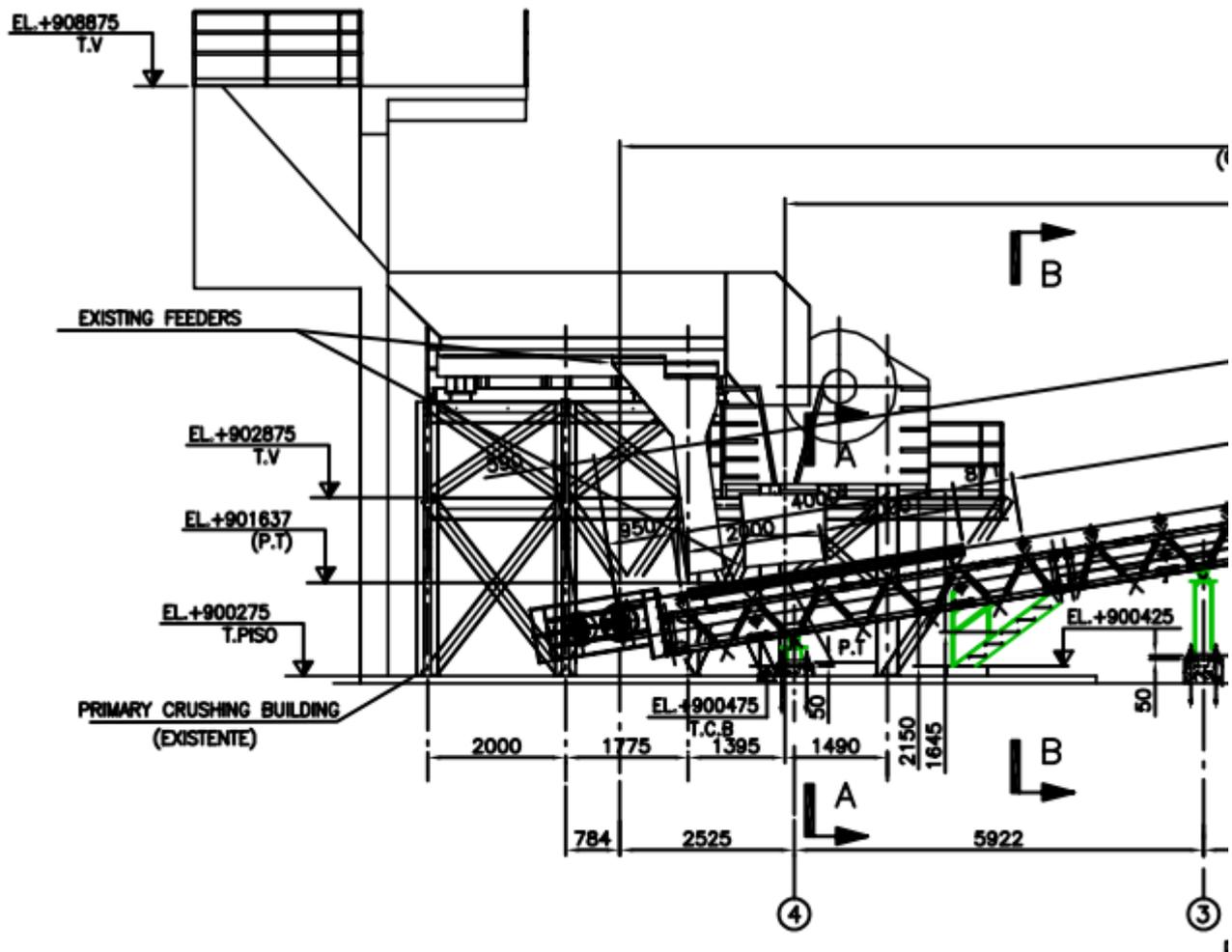


Figure 6- Survey Conveyor: Detail From Elevation View.

The standard NBR 9050 recommends the minimum passage height to be 2100mm for accessibility to buildings. This project problem was highlighted by about 80% of the survey participants.

5. CONCLUSION

Based on the standards and Brainstorming technique, we can see that the design of the in-question conveyor must be reviewed because it puts operators at risk and does not follow current regulations.

In the Brainstorming meetings, the comments from the participants were similar regarding the equipment design. In many moments of the meetings, they reported experiences and accidents that occur due to this type of design error.

It is extremely important to mitigate these risks in the design phase, avoiding risks and accidents and minimizing economic impacts.

To minimize this type of incidence in projects, the teams must be trained on the current norms. It was recommended lectures involving more experienced professionals about the risks that design errors can cause. This way designer will have more attention about some aspects of the conveyor design to avoid future accidents.

For future work, it would be interesting, using the Brainstorming technique, to analyze the drawings before and after revisions.

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