CNT - Confederação Nacional dos Transportes

DB - Deutsche Bahn

ITL - Instituto de Transporte e Logística

International Certification in Management of Rail and Metro Rail Systems

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# Study on technology applications to reduce error and incidents caused by human factors on the railway

**Final Project**

**Brasília**

**2020**

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Final Project presented to ITL – Transport and Logistics Institute, CNT - National Transport Confederation, as part of the requirements for completion of the International Certification In Management of Rail and Metro Rail Systems course.

**Brasília**

**2020**

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And above all, we thank Rumo Logística for the sponsorship and giving us the unique opportunity to participate in this course, Investing in our professional development.

## ABSTRACT

The human factor is responsible for several incidents and accidents in the railways. The objective of the project is to research human error and their causes in addition to technological features, application or devices, that can mitigate the risks related at this factor, applying, e.g., artificial intelligence allied with neurological science to check if a person is able to perform his role. The result of the project will open a new window for technology applied in the brazilian railways, helping the rails to be more safe and secure for the employees, the society and all the stakeholders of the operations.

## RESUMO

O fator humano é responsável por diversos incidentes e acidentes nas ferrovias. O objetivo do projeto é pesquisar o erro humano e suas causas, além de recursos tecnológicos, aplicativos ou dispositivos, que possam mitigar os riscos relacionados a este fator, aplicando, por exemplo, inteligência artificial aliada à ciência neurológica para verificar se uma pessoa é capaz para desempenhar seu papel. O resultado do projeto abrirá uma nova janela para a tecnologia aplicada nas ferrovias brasileiras, ajudando os trilhos a ficarem mais seguros para os colaboradores, a sociedade e todos os stakeholders das operações.

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## LIST OF ABBREVIATIONS AND ACRONYMS

**ANTF**: Associação Nacional dos Transportadores Ferroviários (National Association of Freight Railways)

**ANTT:** Agência Nacional de Transportes Terrestres (National Agency of Land Transport)

**BRL:** Brazilian Reals (currency)

**PPI**: Programa de Parcerias e Investimentos (investment partnership program)

**RMN**: Rumo Malha Norte

**RMO**: Rumo Malha Oeste

**RMP**: Rumo Malha Paulista

**RMS**: Rumo Malha Sul

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# 1 INTRODUCTION

## 1.1 Initial considerations

### Brazilian Rail Cargo Sector

With 29,320 km, Brazil's cargo transport railways connect the main mining, steel, industrial and agricultural areas and the most important Brazilian export ports. Brazilian Railways logistic system, transport more than 95% of the minerals reach the ports for exportation and more than 40% of the exported agricultural solid bulk. In the figure below, we can see the extension and distribution of the Brazilian railway network already granted to the private sector, in addition to the main projects of the Ministry of infrastructure and private companies that are in progress through the investment partnership program - PPI.

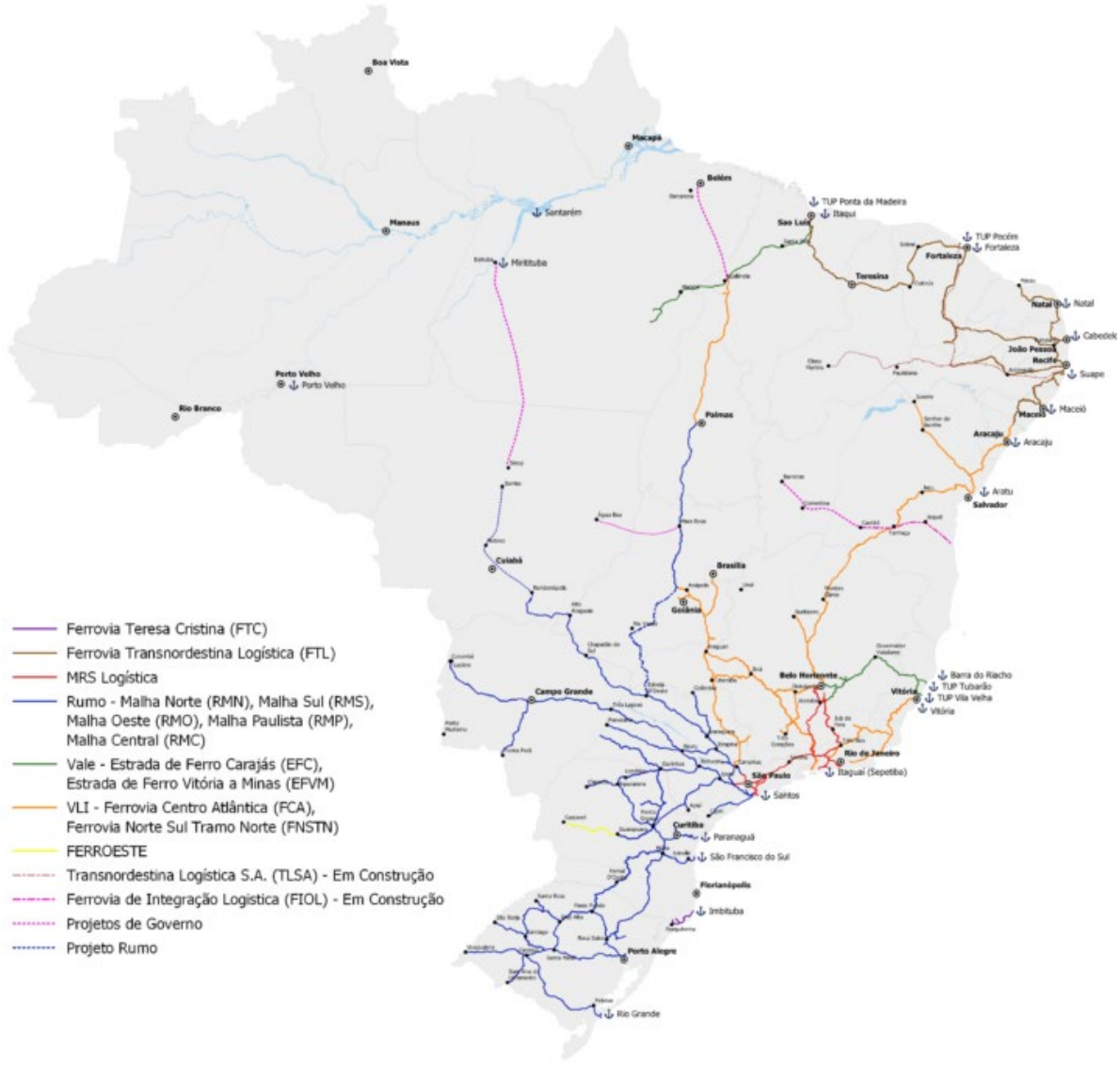



FIGURE 1 - BRAZILIAN RAILROAD MAP

According to ASSOCIACÃO NACIONAL DOS TRANSPORTADORES FERROVIÁRIOS – ANTF, Brazilian railway development has always been closely linked to government policies, which have undergone great variations throughout history. In order to systematize this relationship, ANTF divided the evolution of the railway system according to chronological phases, correlated to periods of Brazilian imperial and republican history. According to studies by engineer José Eduardo Castello Branco, railway evolution in the country observes the following sequence of facts:

**Phase I (1835 - 1873):** during the Regency and the Second Reign, observing the beginning of the implantation of railroads in Brazil and the development of this transport system in a slow way, through essentially private companies.

**Phase II (1873 - 1889):** covering the Second Reign and characterized by an accelerated expansion of the railway network, through private entrepreneurs, stimulated by the interest guarantee institute.

**Phase III (1889 - 1930):** encompassing the Old Republic, with an accelerated expansion of the network still being observed, however with the state being forced to take control of several companies in financial difficulties.

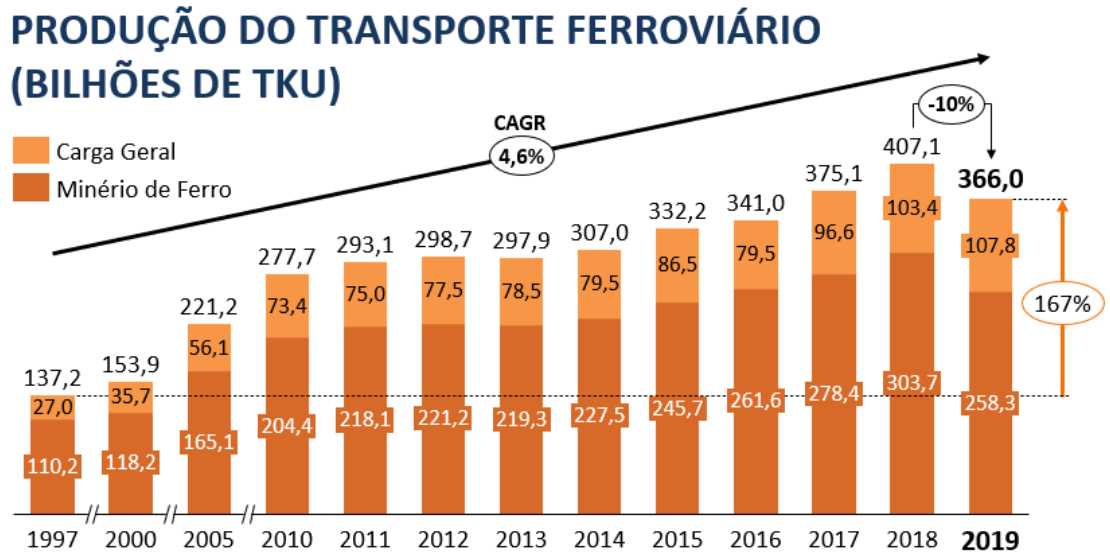
**Phase IV (1930 - 1960):** comprising the Vargas and post-war era, with the pace of expansion slowing down and broad state control over formerly private companies.

**Phase V (1960 - 1990):** located almost entirely during the period in which the nation was governed by a military regime, with the network consolidated in a few public companies, with the eradication of uneconomic branches and the implementation of selective projects of a character strategic.

**Phase VI (1990 - 2020):** New Republic period, marked by the concession of the entire national rail system.

Since the sixth phase and its more than two decades of concession to the private sector, rail freight transportation has undergone a profound transformation. Freight railways significantly increased the volume transported, having in 2019 transported 493.8 million tonnes (TU), an increase of 95% since 1997 - the time when the concessions started, when 253 million tonnes were handled

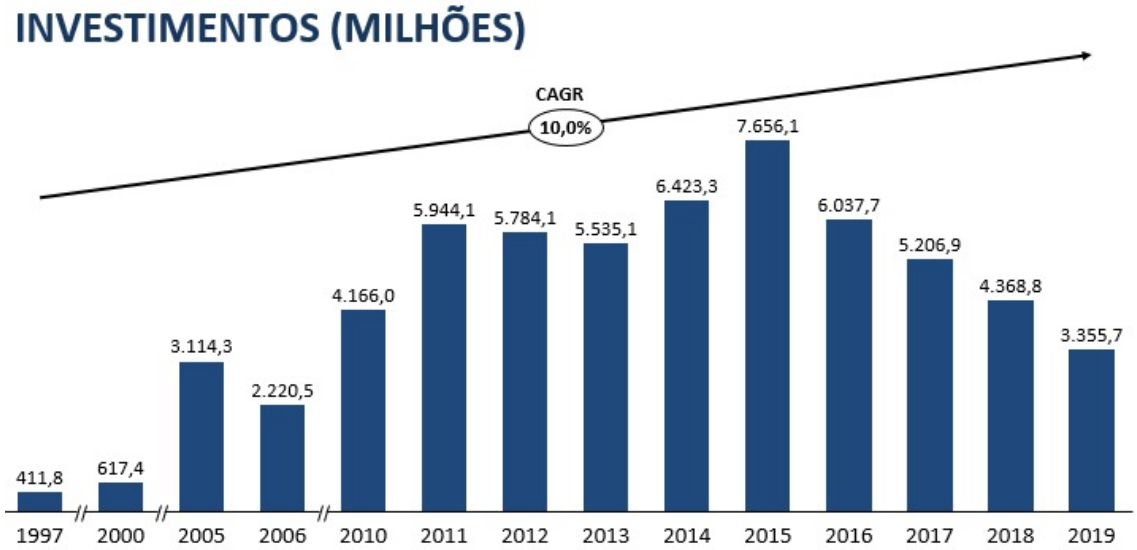
Analyzing the productivity data in RTK (unit of measurement that indicates the amount of useful tons transposed by each unit of kilometer) of the railways after the concession phase, we can see a growth of more than 167%, leaving 137.2 billion RTK to 366 billion RTK. With practically constant growth and a Compound Annual Growth Rate (CAGR) of 4,6% both in its largest share, which is the transport of iron ore, and in the transport of general cargo. Occasionally in 2019 there was a reduction in the volume transported of iron ore due to a reduction in commodity production in Brazil. The graphic below taken from the ANTF website, show this increase of productivity along the years (TKU is the Brazilian unit for RTK).




**Fonte:** ANTT, Compilação ANTF.
**Nota:** TU = Toneladas Úteis. / TKU = Tonelada Quilômetro Útil Transportada

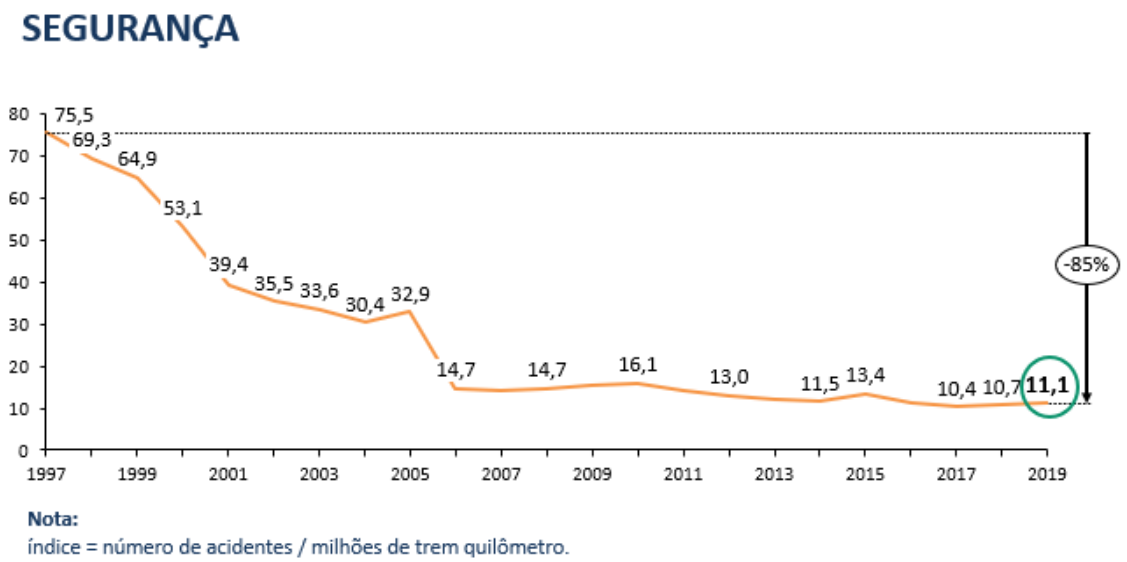
GRAPH 1 - EVOLUTION OF RAILWAY PRODUCTIVITY AFTER CONCESSION TO THE PRIVATE SECTOR

This growth is largely due to the massive investment made over the years by the private sector, where more than R$ 75 billion was invested in the recovery of the network, renovation and purchase of rolling stock, in addition to the implementation of new technologies. The graphic below taken from the ANTF website, show the amount of investments realized by the companies along the years.




GRAPH 2 - INVESTMENT DONE IN THE RAILWAY AFTER CONCESSION TO THE PRIVATE SECTOR

Safety is a predominant factor of success for improving the result of railways in Brazil. After the concessions safety results have also shown a significant improvement over the years, reaching a reduction of 85% between 1997 and 2019 as we can see in the graph below taken from the ANTF website.




**GRAPH 3 - RAIL SAFETY INDEX OF BRAZILIAN RAILWAY CARGO TRANSPORTATION SECTOR ALONG THE YEARS OF CONCESSION**

Despite all the growth over the years, we can see a great development opportunity for the modal in Brazil. In the image below we can see the share of rail transport in green (15%) in relation to other countries of the same territorial size, showing that the density and share of the rail modal in the transport and infrastructure sector in Brazil is still low in comparison with others continental countries.

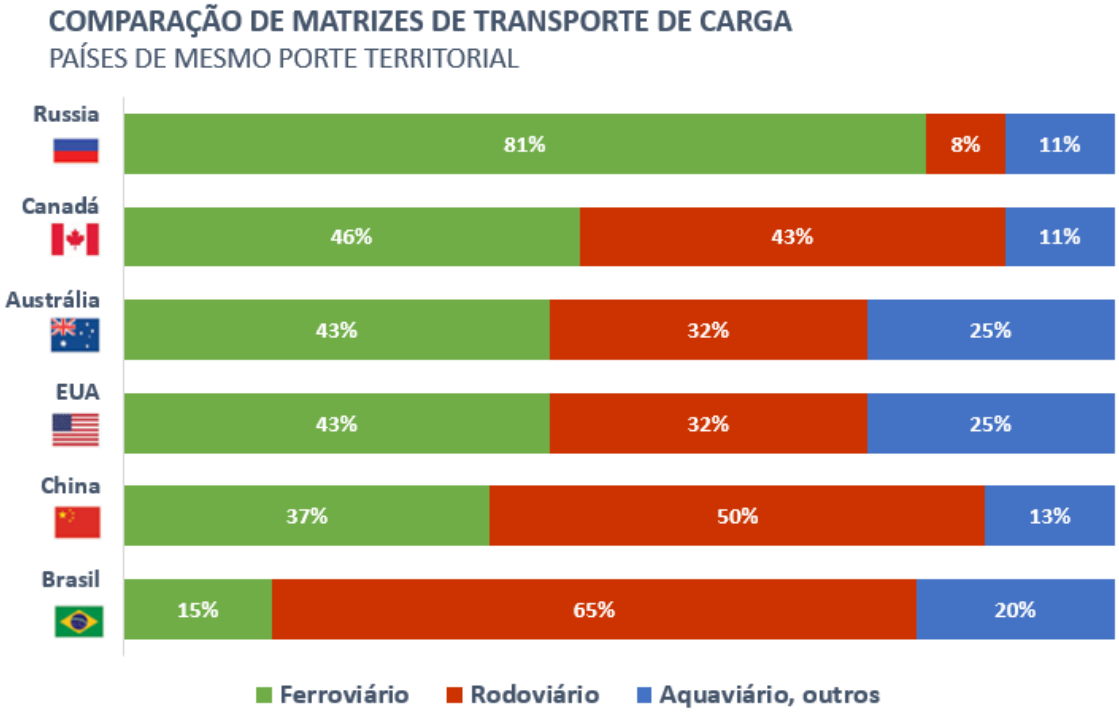



FIGURE 2 - SHARE OF RAIL TRANSPORTATION (GREEN) OF CONTINENTAL SIZED COUNTRIES

Given that much of this work and research will be carried out using data from the company RUMO S.A, in the following topic we will detail a little more about the company, its structure and operation.

## RUMO S.A

Rumo S.A. is the company resulting from the incorporation of ALL by Rumo Logística, completed in 2015, and offers logistic services for rail transportation, port elevation and warehousing. Rumo's main area of activity extends over the states of Mato Grosso and São Paulo and the states of southern Brazil, where four of the country's most active ports are located and through which most grain production in Brazil is exported.

The figure below shows the company timeline:

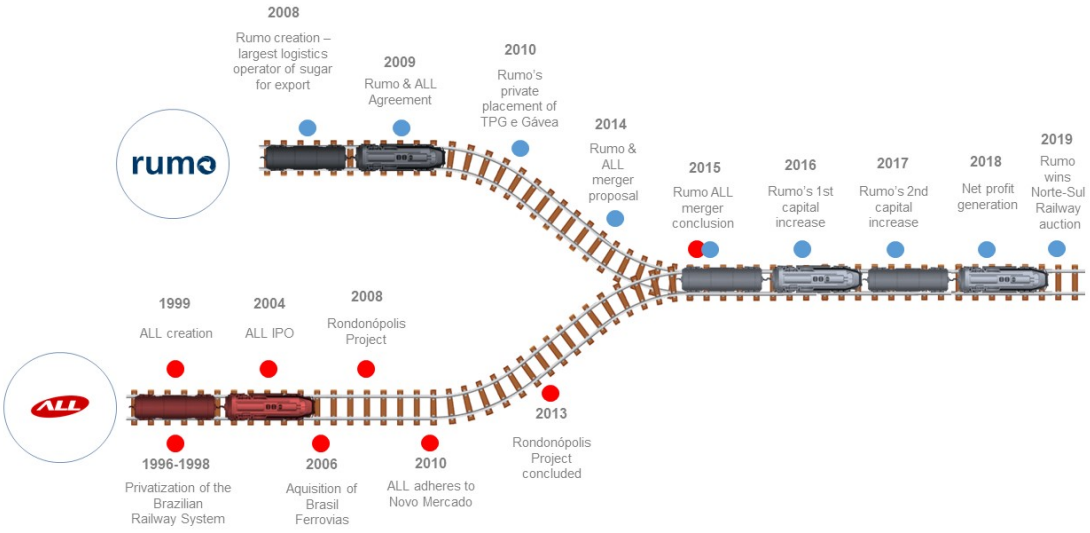



**FIGURE 3 - RUMO S.A TIMELINE**

The Company owns and operates a large asset base, including a rail network consisting of five concessions with approximately 13,500 kilometers of lines, 1,200 locomotives and 33,000 wagons, as well as distribution centers and storage facilities. In this way, the Company operates 12 main transshipment terminals, both directly and in partnership, with a static storage capacity of approximately 900 thousand tons, where we can store grains, sugar and other commodities, which, in the Company's view, allows offer a complete and efficient logistic service to customers. Among these assets, stands out as more important the logistics complex of Rondonópolis (MT), with a monthly loading capacity of more than 1 million tons.

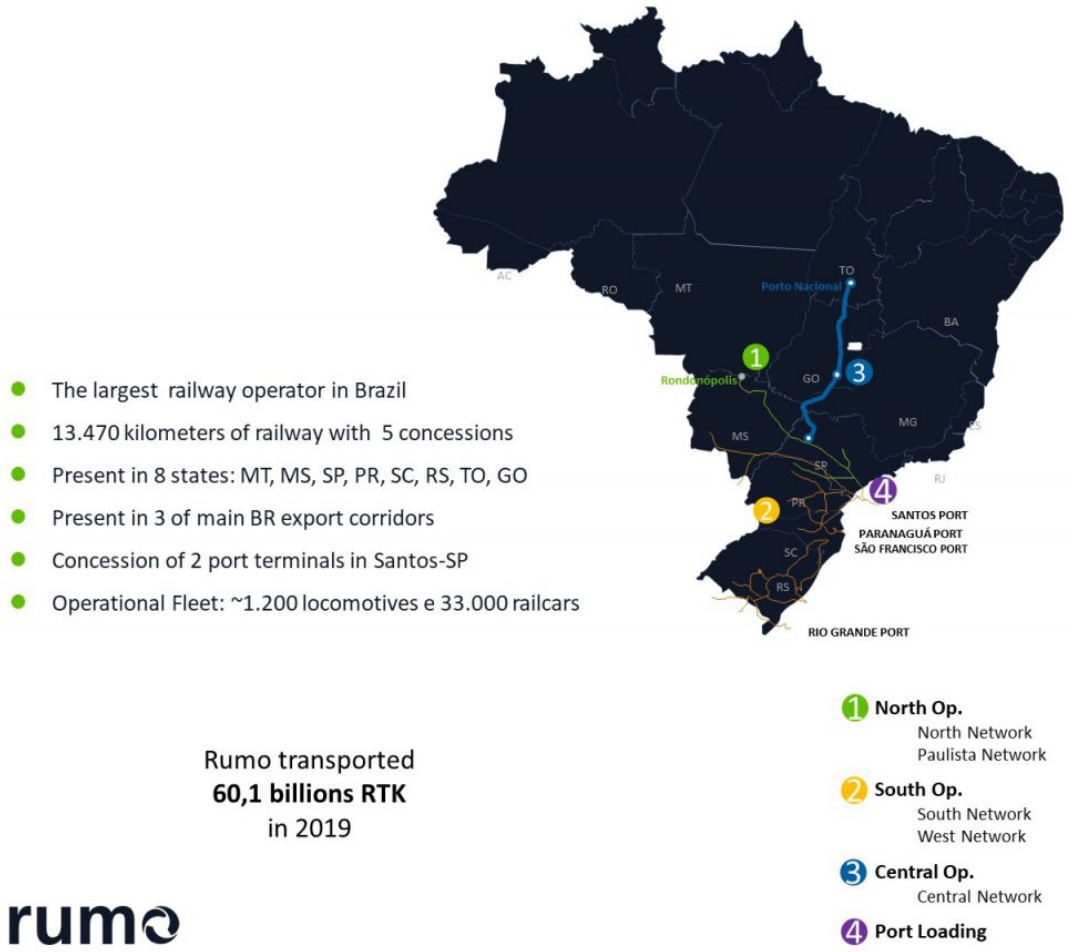



FIGURE 4 - RUMO S.A OPERATIONS

In addition, RUMO S.A control two terminals in Santos and have a stake in four port terminals, three of them located in the port of Santos (SP) and one located in the State of Paraná, with a static storage capacity of approximately 1.3 million tons and one total lifting capacity of approximately 29 million tonnes per year. The land that Rumo leased under its concessions includes areas available for construction and development of warehouses and logistics terminals in Brazil, which enables an even greater expansion of operations, as well as the improvement of the Company's logistics and other services.

The Company is organized in business units which represents the networks and the main market sectors that operate. Rumo's business units are North Operation composed by the North Network, Paulista Network and Port Operation in Santos, South Operation composed by West Network and South Network and Containers Operation comprised by its subsidiary Brado Logistica and other results of container operations.

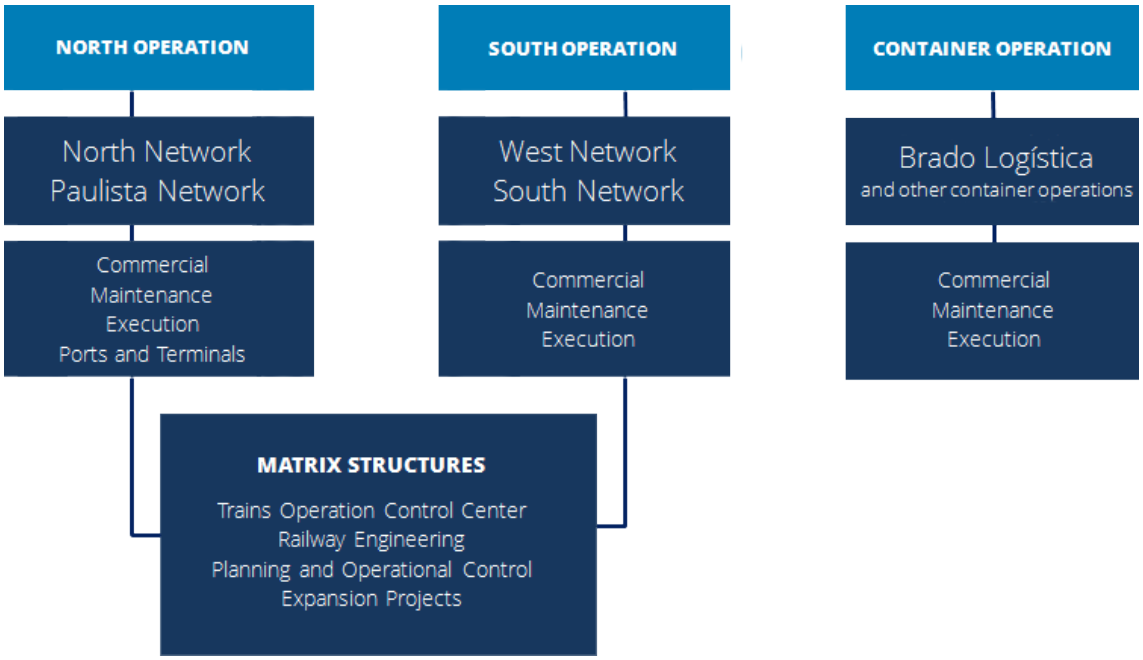



**DIAGRAM 1 - RUMO S.A BUSINESS UNITS**

Northern Operations comprise the concessions held by the subsidiaries Malha Norte and Malha Paulista. Moreover, Rumo has important transshipment terminals in the states of Mato Grosso and São Paulo, in addition to the T16 and T19 port terminals, which Rumo fully owns, and certain other terminals in which the Company holds equity interests together with strategic partners, namely Terminal XXXIX (49.6%), Terminal Marítimo do Guarujá S.A. – TERMAG (19.9%) and Terminal de Granéis do Guarujá S.A. – TGG (9.9%).

Through Northern Operations, Rumo primarily transports agricultural commodities such as grains (soybean, soybean meal and corn), sugar, rice, wheat and fertilizers. Rumo also transports industrial products such as fuels, paper and pulp. The network that comprises Northern Operations extends over a large part of the agricultural production areas of Brazil located in the states of Mato Grosso and São Paulo, and is consequently the most important operation of the Company, accounting for approximately 71% of Rumo's rail transportation volume in 2019.

Northern Operations' main customers in the rail transportation segment are grain traders, including Bunge, Amaggi, Cargill, ADM and Louis Dreyfus, among others

Southern Operations comprise Malha Oeste and Malha Sul, whose railways encompass the states of Mato Grosso do Sul, Paraná, Santa Catarina and Rio Grande do Sul. In addition, it has important inland transshipment terminals in the states of Paraná and Rio Grande do Sul, and operate terminals at the ports of Paranaguá in the state of Paraná, São Francisco do Sul in the state of Santa Catarina and Rio Grande in the state of Rio Grande do Sul.

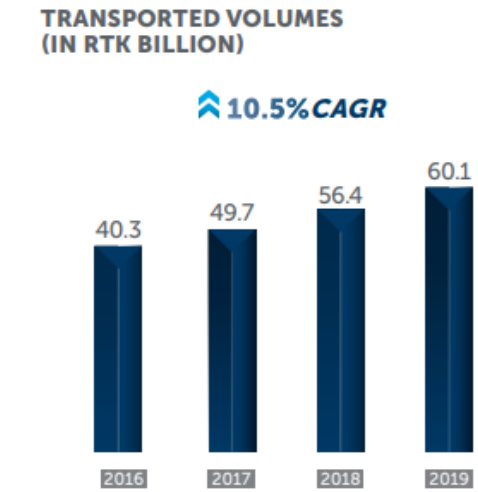
In addition, in Southern Operation, the Company has major transhipment terminals in the interior of the States of Paraná and Rio Grande do Sul, and operates terminals in the ports of Paranaguá (Paraná State), São Francisco do Sul (Santa Catarina State) and Rio Grande (State of Rio Grande do Sul).

Southern Operations primarily transport agricultural commodities such as grains (soybean, soybean meal and corn), sugar, rice, wheat and fertilizers, as well as certain industrial

products such as fuels, pulp and paper. The main customers in this segment include Santa Terezinha and Bunge.

The Container Operation comprises the operations of Brado Logística, in which Rumo holds a 61.71% stake. In the Operation of Containers, the Company transports agricultural products as well as industrial products and consumption goods.

Rumo is one of the main providers of logistics services in the agricultural sector in Brazil . This becomes even more relevant when considering that this type of service is of great importance to the development and growth of the country, considering that Brazil is one of the main producers and exporters of agricultural products in the world. RUMO's results in transported volume have been growing annually. Since 2016, transported volume has grown at a compound annual rate (CAGR) of 10.5%. The figure below shows the evolution of Rumo transport result over the years.in billions of RTK

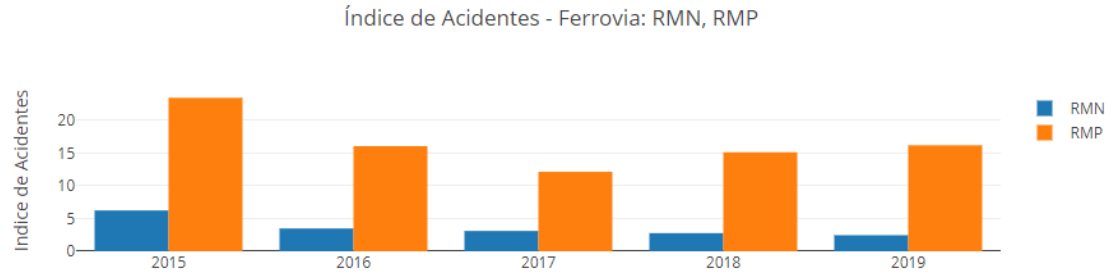



GRAPH 4 - EVOLUTION OF VOLUME TRANSPORTED BY RUMO IN RTK

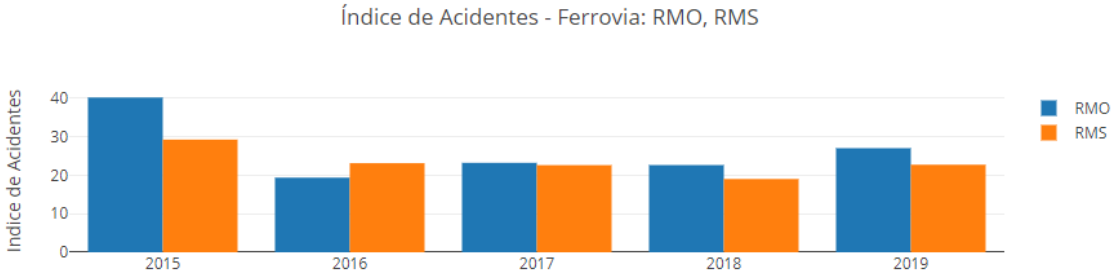
One of the commitments of Rumo strategy for sustainable development is to ensure the safety of teams, processes and operations

According ANTT - Agência Nacional de Transportes Terrestres (National Agency of land transports), and especially in the railways concessioned to Rumo, there is a decrease in the rail incident index [1]that we can see in the figures below.

[1] Index calculated by the formula: Index = number of accidents/distance traveled by trains




**GRAPH 5 - EVOLUTION RMN (RUMO NORTH NETWORK) AND RMP (RUMO PAULISTA NETWORK) RAIL ACCIDENT INDEX**

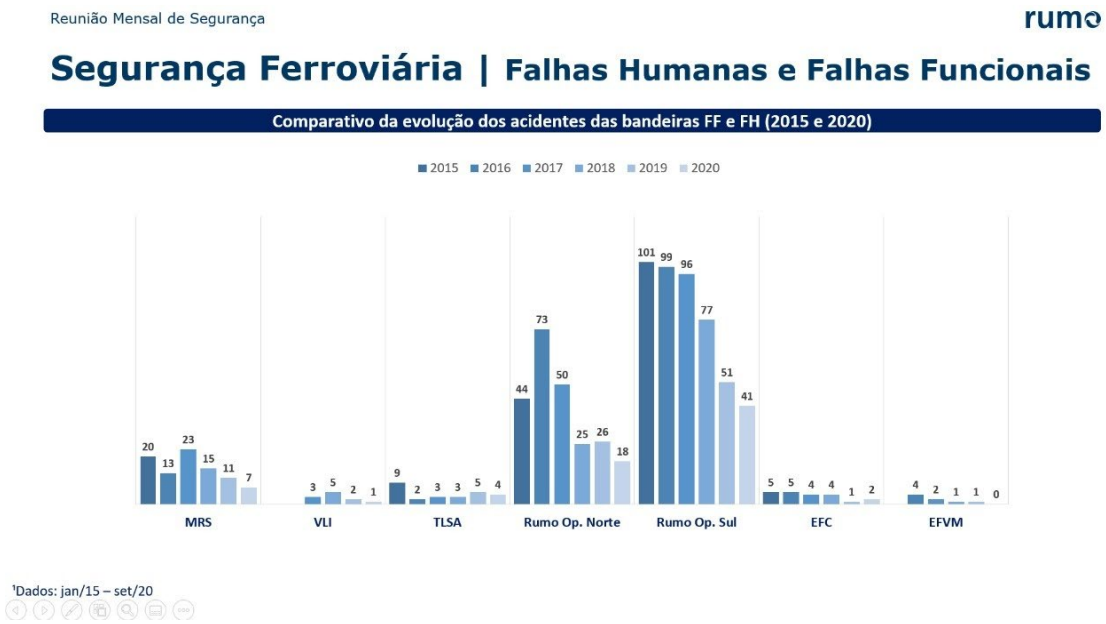



**GRAPH 6 - EVOLUTION RMO(RUMO WEST NETWORK) AND RMS(RUMO SOUTH NETWORK) RAIL ACCIDENT INDEX**

Even with the significant reduction in the number of rail accidents in Brazil, and especially in Rumo concessioned Railways, the relentless pursuit of operational safety is an extremely relevant term for the railroad development strategy in Brazil and especially for Rumo's business plan. Many gaps can and must be resolved to achieve a more sustainable and secure operation. Rail accidents have already cost about R$ 300 million to Rumo between 2016 and 2018, and these values could increase the company's results, instead of becoming costs.

## 1.2 Work Justification

As we seen before, safety is one of the most relevant themes for a Railroad success, and for Rumo it is a part of the business strategy and commitment for a sustainable development plan. The human factor is responsible for several incidents and accidents in the railways, as we see in the figure below showing the number of rail accidents caused by human and functional failures from 2015 to 2020 on Rumo and other railways in Brazil.




GRAPH 7 - EVOLUTION ACCIDENTS CAUSED BY HUMAN AND FUNCTIONAL ERRORS OF BRAZILIAN FREIGHT RAILWAYS

Even though the number of accidents has decreased a lot over the last few years, there are still a large number of accidents caused by human factors, especially on the railroads operated by Rumo. This work seeks to analyze and find ways to fill this gap at Rumo operations.

### 1.3 Goals

The objective of the project is to research human error and their causes in addition to technological features, application or devices, that can mitigate the risks related at this factor, applying, e.g., artificial intelligence allied with neurological science to check if a person is able to perform his role. The result of the project will open a new window for technology applied in the Brazilian railways, helping the railway operators to have a safer and secure operation for the employees, the society and all the stakeholders of the logistic system.

### 1.4 Scope of Work

The present work focuses on analyzing and comparing incidents caused by human factors in the railway operation of the company RUMO SA and in other Brazilian railways operators, in addition to bringing research on possible technological solutions applied in railway operations, and other sectors of transportation, logistics and operations around the world that could avoid, mitigate risks or reduce the impacts of the analyzed incidents.

### 1.5 Work Structure

The work is structured in five phases that address the following topics:

• **Chapter I: Introduction** - Initial Considerations, Work Justification, Work Goals, Work Scope, Work Structure;

• **Chapter II: Preliminary Remarks** - A Literature Review with Theoretical Foundation, Background and Critical review about Human factors and Human errors;

• **Chapter III: Hypotheses and Research Results** – Human factors incidents at Brazilian Railroads and at RUMO S.A,

• **Chapter IV: Project Plan**, Risk Analysis, proposal of solutions, ideas for Technology application to reduce risks, cost Benefit Analysis;

• **Chapter V: Final Considerations**

## 2 LITERATURE REVIEW

In this stage of the project we will make a brief reference on the subject of human factors based on the concepts applied by the guide and research of the RSSB (Rail Safety and Standards Board) and HSE (Health and Safety Executive) on human factors applied in the railroad. The current work brings a little of the concepts applied by the ERA (European Union Agency for Railways) to understand the accidents caused by human failures on the railways in Brazil, especially RUMO S.A.

According to HSE "Human factors refer to environmental, organizational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety". Aiming to increase human performance for a safer and more efficient operation the human factor science understands the interactions among humans as individuals and other elements of a system, the job and the organization as illustrated in the figure bellow:

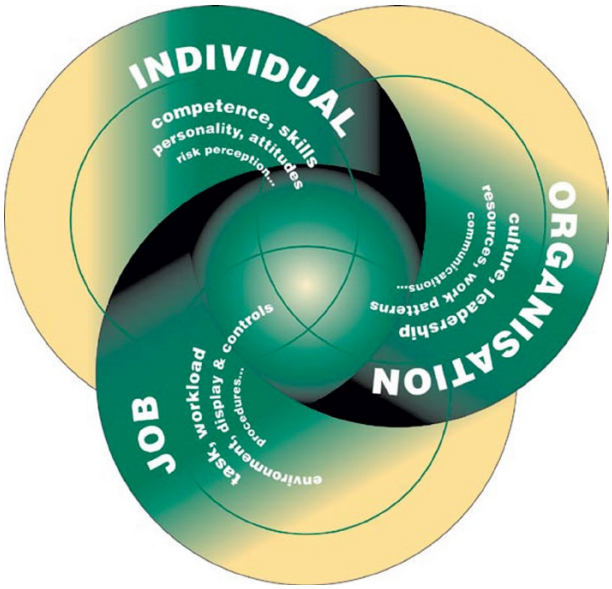



FIGURE 5 - HUMAN FACTORS IN OCCUPATIONAL HEALTH AND SAFETY

**The job** – As shown in the picture above tasks, the environment, display and controls, job procedures and other job design factors, should be built to fit the individual ergonomics and organization needs. A correct job design must guarantee the individual's physical and metal correspondence so that the work is effective for the business results and safe for the people involved in it.

**The individual** – Every person bring to their job their individual attributes like competence, skills, personalities, attitudes and risk perception. Individual characteristics influence behavior and task performance in ways that can be positive or negative to the safety of the job or organizational needs. Some characteristics such as personality are fixed and cannot be changed. Others, such as skills and attitudes, may be changed or enhanced. It is important to understand these characteristics so we can manage it to fit the job and the organization.

**The organization** - Organizational factors and culture influence individual and group behavior. The Organization need to establish a positive health and safety culture.so the employees are involved and committed at all levels with safety. This culture must guide Individual behavior and orient the job design.

Understanding human factors knowledge and techniques allow the railroad operators to reduce errors, increase safety and increase productivity, as the whole organization, the job structure and the individuals have a better fit and human performance increases.

According to RSSB and the Safety Management Information System (SMIS) incidents can be classified as human performance or 10 incident factors as show at the figure below.

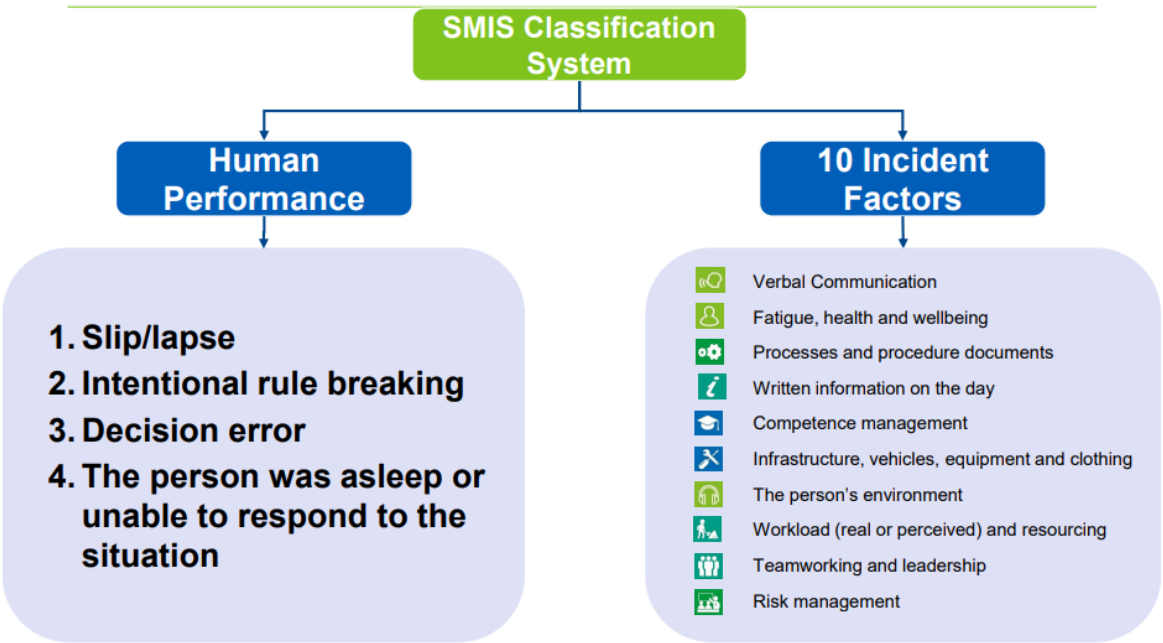



FIGURE 6 – SMIS ACCIDENT CLASSIFICATION SYSTEM

Below is a summary of the 10 Incident factor:

- Verbal communication – Failure between exchange of spoken information between staff
- Fatigue, health and wellbeing – Individual conditions leading to incidents

- Process and procedures documents – Wrong process and procedures that lead to incidents
- Written information on the day – Failure in written information that guide staff activities
- Competence management – Selection, training and assessment failures
- Infrastructure, vehicles, equipment and clothing – Failure in equipment and infrastructure used do undertake or support the task.
- Person Environment – Environment stressors that can lead to failure (lighting level, noise, temperature)
- Workload and resourcing – a load of work that exceed the individual capacity leading to failure
- Teamworking and leadership – Failure in people organization to work together or leadership, leading to mistakes
- Risk management - Fail in a process used to identify , assess ,reduce and monitor safety concerns

For a better understanding of the influence of the human factor in the railway industry, RSSB divided the Human factor influence on human performance in five critical areas. The figure bellow shows the five critical areas, staffing, training, design, culture, conditions and the subtopics

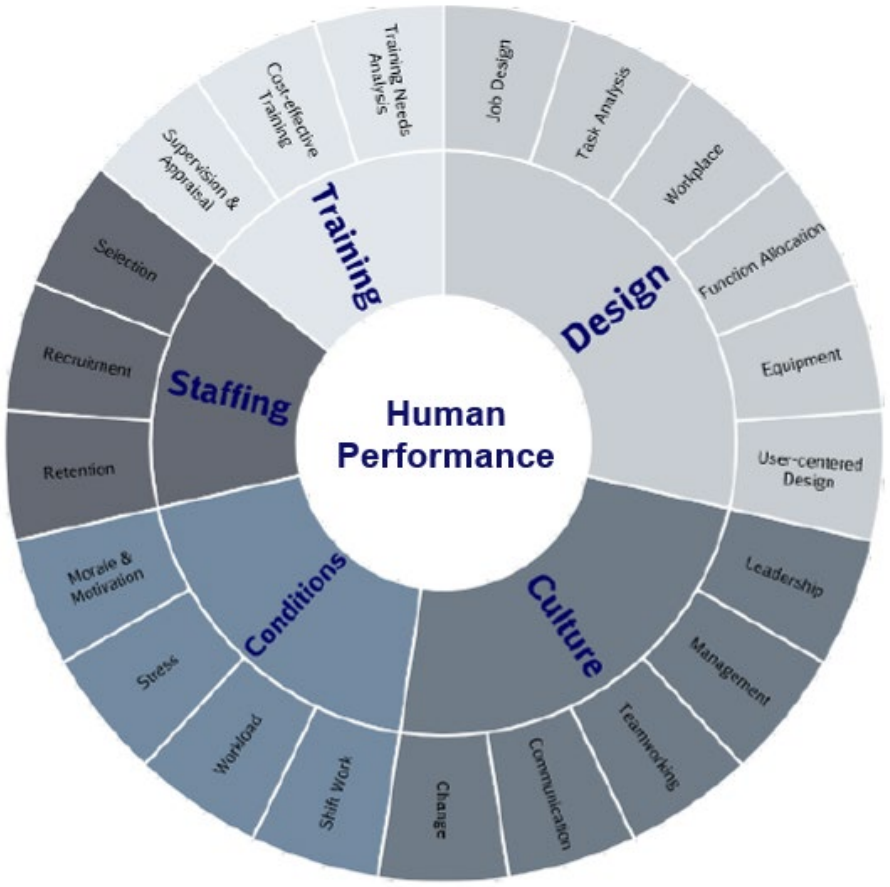



FIGURE 7 - CRITICAL AREAS OF HUMAN FACTORS

**Design**

Everything that is produced and used on the railroad goes through a design stage. Design is used to generate a product for a specific purpose. Products can be equipment, processes, procedures, rules and rule books, etc. In the design phase, you must define how the products will be used and what problems they will solve. The usability of a product depends on several important human factors issues, including:

- The user understands and think it is easy to know the function of the product?
- Operation of the product is straightforward and safe?
- The product supports the user's task?
- The product fits with related organisational products and their users?

Failure to take human factors into account can lead to errors that seriously degrade performance, lead to accidents, loss of customers, waste and financial costs.

The main topics, which should be taken into account in design, presented in the previous figure, to guarantee a safer operation and with better human performance are:

- Job design – Defines tasks and roles for the individual job;
- Task analysis – Understand and define tasks needed to do the job;
- Workplace Design – define the correct workplace for the job to be done;
- Function alocation – define what part of the system the equipments or operator are going to do;
- Equipment design – Define good equipments to fit for a purpouse, the principles used for a good equipment desing are visibility, feedback, natural mapping, affordances, constraints, convetions, environment, workflow and workload;
- User centered design – Users are involved as a main part of design process, granting a good user experience and usability.

**Training**

People need to be developed to meet the needs of the organization and develop their potential. Training should be practiced as a continuous method to obtain the best result from people. For the training, to be efficient and cost-effective, it is necessary to evaluate the correct time to carry out the training, which skills, which people and how it should be carried out. The main topics, which should be taken into account in training, presented in the previous figure, to guarantee a safer operation and with better human performance are:

- Training needs analysis – Identify training requirements and their implications for the individuals thar works in the organisation;
- Supervison and apraisal – Supervisory skills responsible for the continuous development of front line staff in the railway industry;
- Cost effective training – Use of correct training methods for an effective training

**Staffing**

Organizations need the right number of people in the right places and doing the right tasks at the right time. In addition, they must control human resources in order to maintain a good team. Selecting and retaining the right people is essential to an organization's success. Failure in selection and defining the work team can lead to disconnection and failures that are costly or that affect safety. The key topics that should be taken care of are:

- Selection – Define the correct selection process and tests to have the righ people at the right place;

- Recruitment – Use correct methods to recruit good candidates for the job
- Retention – Using methods to retain a good team is a key topic to keep performance, as training and staffing can take a long time and can be really expensive

**Culture**

Each organisation develops its culture. Culture is guidance for the way people behave with each other. An organisation's culture appears in the leaders and the teams behaviour and also in the way people communicate with each other. It's responsible for how an organization can adapt and respond to change, and how the whole organization can change. An organization can not change culture directly. But it can find way to influence people's behaviour, by giving concience, changing acts and attitudes, to create habits and then build a culture that encourages the desired behaviour. The key topics of culture are:

- Leadership - Leaders have an important role in forming the organisational Culture, since their behavior can guide others
- Management - Managers are responsible for ensuring that the necessary things get done in the organisation, and that they get done properly, and culture is a part of it.
- Teamwork - A central part of any organisation's culture is how people relate to, and work with, each other.
- Communication - communication is not only a manifestation of the culture; it is also the main mechanism for spreading and institutionalising the culture
- Change - Any organisational change is only true change if it lasts and transforms the nature of the organisation in some way or, in other words, involves a change in culture

**Conditions**

Work conditions, like workload, work shift, morale, motivation ,stress and wellbeing are important human factor influences in humam performance. The key topics of conditions are:

- Morale and Motivation – People with low morale and motivation have constant performance issues, the organization should use the correct methods to keep the staff with high morale and motivation;
- Stress - In a safety critical industry such as the railways, stress is a particular issue because stress makes people less safe. People stress need to be cotroled and monitored to keep a good performance.
- Workload - Crucial human factors consideration for designers and managers. If people have too little to do, they can become bored and inattentive. People with too much workload is a primary cause of stress, which seriously degrades human performance and safety. In either case, there is a major implication for safety operations.
- Work Shift - Poorly managed shift patterns can have wideranging effects on the staff concerned. They can also affect the efficiency and, most critically, the safety of the industry as a whole. It is therefore important to understand the risks and problems associated with different shift work patterns.

**Human Performance**

In the center of the five critical areas is human performance. Within an organisation, human performance is directed behaviour that takes place for some measurable purpose. The

reults of this performance and behaviour is influenced by external conditions, like environment and culture, by internal psychological, physiological and anatomical factors. Even though, it is possible to control some external and manage some internal factors, some characteristics are intrinsic to human behaviour. People will make mistakes and break rules, people will take risks and accidents will happen. For a better management of human performance, organisations should use the knowlodge and guidance of the five critical areas shown above, but it is important to understand how people behave. The figure below show the four critical questions about human behavior at work, that affect Human perfomance.


FIGURE 8 - FOUR CRITICAL QUESTIONS IN HUMANS FACTORS

**Why do people make mistakes?**

Rasmussen's Skill-Rule-Knowledge is a well-known model for understanding and human mistakes in rail occurrences (Rasmussen, J.1987). The model divides in three types of performance that can lead to human errors.

***Skill-Based Behavior***

Skill based behaviors occur on stored physical or motor routines, they are habits learned with practice and may be occur unconsciously. The most common errors involving skill-based behavior happens when the operator is fatigued, preoccupied with something, or is too much relaxed. Skill-based errors are common committed by experienced people, that already have skills and don't stop to think about what they are doing.

Errors associated with skill are based in slips or lapses. They occur due lack of attention and fail to monitor actions. Below are some types of slips and lapses:

- Familiarity slips – This slip occur when the person switch some activity to another based on his familiarity of the task. A good example for this slip is when you need to make a phone call to someone and you miss it because you called a very frequent called number.
- Similarity slips – This occur when the task that must be done have some similarities to another frequent done task.In this case the operator do a correct task but in a wrong context or equipment.
- Memory lapses – This occur when the operator forget why he is doing this task, or jumps one of the steps needed to complete the task correctly. Like a memory shut down, people do the task in an automatic mode.
- Association slips – It occurs when the individual makes a faulty association between two ideas, it is common to occur when ideia is an external stimulus that provokes a action and provoking the mistake.

### *Rule-Based Behavior*

Rule based behaviors occur based by learned routines or procedures. They are stored as rules in long term memory., When actioned, these skills involve the working memory and central decision maker because as they are actioned at a conscious level. Working memory is involved as the individual must follow of the procedure to deal with the situation going on. Errors occur by the individual making a misidentification of a problem, using a wrong procedure. Sometimes when the individual identifies the correct problem, it can apply an incorrect procedure. Below are some other common rule based mistakes:

- Misapplying a good rule – applying a good rule in a situation that it was not supposed too.
- Applying a bad rule – the task is done correctly but the consequences are different then it supposed to.
- Failing to apply a good rule – when the individual doesn't apply or make a mistake while applying a good rule in a situation that it was supposed to.

### *Knowledge-Based Behavior*

Knowledge based behaviors occur based on the knowledge and experience of the individual, where there is no procedure or rule for the situation. Mistakes occur when the individual is misled by their knowledge or experience through their biases and heuristics.

Knowledge-based performance is prone to mistakes, even more of a complex nature. They occur from uncertainty, low knowledge, low concentration, or a misapplication of knowledge. Below are some examples of common errors:

• Availability bias – choosing a course of action because it is the one that comes most readily to mind.

Confirmation bias – use only information that confirms what the individual believe about the situation and ignoring things that disagree with the current belief.

These biases can lead people into wrong conclusions and failure to complete tasks with safety.

**What causes errors?**

Errors are not events that happen randomly. They are not a cause of an incident, they are a consequence of what goes on in our mind, inattention, lack of knowledge, sparse sensory data, mis-perceptions, memory lapses, relationship conflicts, family, and so on. Many of these factors are shaped or potentialized by work environment, including the work climate, the management culture, leadership behavior and working conditions.

One of the main causes of human failure is the diversion of attention. This deviation can occur due to environmental factors, such as noise, use of smartphones, other people's actions; physiological causes, fatigue, lack of sleep, use of alcohol or drugs and diseases; psychological factors, such as having to perform multiple tasks, boredom, stress, fear, frustration, anxiety, anger and personal problems.

**How can you reduce errors?**

Error management must be set up to suit specific contexts in each organization. The challenge for organizations is to develop a fair work environment where people can be open to talk about their mistakes without fear of severe punishment, and share experiences to learn from their mistakes. It means combining techniques in the most efficient way in the five critical areas of human factors mentioned above.

Design is used to assist users to rethink their decisions before executing them or to ensure that they do not make mistakes. Automation may seem like a good solution because it reduces human influence, but it can be misleading, just by changing the problem to human interface and equipment. Automation can also fail and create problems for a user who is bored or unaware of the equipment.

Training - People are trained and use it to perform their activities without errors. However, training needs to be well planned to be effective. Violations are best addressed by making it clear what the consequences of the acts are, and technical failures can be addressed with knowledge, habits and rules.

Staffing - is used to recruit and select people with the right skills, and the learning ability to conduct work flawlessly, and thus ensure that the right people are put in the right roles.

Culture - is guided by leadership and management, to create a fair environment, where people can share their experiences without fear of reprisals and learn from their mistakes in a way that has an engaged team, and work as a team to avoid failures

Conditions - used to identify and correct adverse work conditions such as stress, work environment, workload, multiple tasks, etc., which can affect the conduct of activities and cause the error.

**Wich error reduction techniques are available?**

Most techniques assess mental behaviors while performing tasks and the boundary conditions that can affect the conduct of work, such as fatigue,

The main techniques are listed below.

- •FTA - Fault tree analysis is used to describe system failures and causes and to estimate their probabilities.
- HEART (Human Error Assessment and Reduction Technique) - is simple and well used by railways and focuses on the factors that have the greatest influence on human error.

- HAZOP (HAZard and OPerability) - is a complete tool, but it takes time and labor. It is widely used on railways, but little used in Brazil, Actual work will use this tool for analyzing incidents. HAZOP focuses on analyzing the security risks caused by people. HAZOP human error, therefore, resembles another widely used technique, HEART, but it is more detailed and comprehensive, and requires greater effort and time to be performed. HAZOP assesses the probability and nature of human errors. A multidisciplinary team with knowledge of the technique must be used to carry out efficient analyzes.
- Murphy diagrams - are very similar to the fault tree analysis, they analyze the apparent causes of the failures in a quick and easy way, and without deepening.
- SHERPA (Systematic Human Error Reduction and Prediction Approach) - is a technique that presents human error prediction in a structured way and also analyzes tasks and solutions for errors.

**Why do people break rules?**

People can break rules without being aware that they are executing a violation, either because they do not know that the rule exists, or because of a failure of memories. To forget its existence, cases like this are translated as failures, and not as a breach of rule itself, and were covered in the previous topic.

There are cases where people deliberately violate rules. Let's deal with this topic a little more below.

Normally rule breaks are not done maliciously, but are done with the intention of the person doing their job in the way they think is most practical. In this case, the Organization created the rule to try to shape the behavior of individuals and the user violates the irrigation to have a better performance or create a shortcut.

The UK railway industry classifies violations as follows:

- Routine violations;
- Situational violations;
- Exceptional violations;
- Personally optimizing violations;
- Sabotage.

According to Lawton (1998) there are four main reasons why employees deliberately break the rules.

- Unusual circumstances. This type of rule break occurs when an unusual sequence of factors creates a favorable scenario for a rule break, as a reaction to these events. These are high-risk, but low-frequency violations - the violations most often associated with deaths from maneuver accidents. They happen when someone is faced with a new problem and needs to use their knowledge to find a solution, for example, when a train needs to be coupled in a curve.
- Situational shortcuts. They happen in difficult conditions, in which the individual finds it easier to use a shortcut to reach a goal more economically, and / or faster. They happen frequently, and are part of routine employee actions. Design is important to mitigate violations of the type, poorly designed equipment generates inevitable violations in a work environment. Often, these types of violations are endorsed by the leadership to achieve better performance.
- Routine shortcuts. They happen constantly, just like the previous one, it is a shortcut, but it happens routinely during work activities. Routine violations are generally high-frequency, but low-risk. Managers imagine that the risks taken are less than people's

skills, and the ability to mitigate them. As the employee gains experience, he has the feeling that these rules no longer apply to him, they end up becoming normal in the work routine of more experienced employees.

- Ineffective supervision. Lack of supervision or flawed supervision allows for violations and shortcuts and in more critical cases sabotage. Judgment errors and additional risks for productivity gains are very common with lack of supervision, in environments with violations and without accidents can still be interpreted as secure and generate complacency and a false sense of security.
  People with the feeling that they will not be fully accountable or that there are more benefits than cost in relation to the consequences of possible failures or accidents generated by the violations are more likely to commit violations. Poorly defined roles, responsibilities and authority also increase the likelihood of violations.
  Organizations tend to suffer greater impacts than people in incidents caused by violations, so the lack of supervision can generate the feeling that it is worth breaking the rules and the personal gains from shortcuts and violations are greater and more visible in the short term than the risk of an incident.

What can be done to reduce the violation of the rules?

- Confirm the need for the rule. Before making the effort to persuade and empower people to follow a rule, check whether it is possible to eliminate the risk of error or simplify the task by eliminating the need for the rule
- Ensure the rule's reliability. In order to maintain the rule's credibility, it must be set up to ensure the safety of people, not just the organization. It is important to be clear that the important thing about the rule is the guarantee of safe behavior, not compliance with the rule itself. It must be updated, feasible and integrated with other procedures of the organization.
- Ensure that the rule is understood. Assess people's real understanding of the rules, ensure that people see value in the rule for safety.
- Ensure that the rule is practicable. If the rule cannot be applied in work situations, or the leadership endorses a rule break to ensure business continuity, violations will become constant and the rule will lose credibility.
- Ensure that the rule is consistent with organizational and team objectives. Rule violations happen to optimize results for a local team, even if it is not beneficial for the organization and security of the whole. It is important to be careful with local goals so as not to generate these types of violations.
- Ensure that the rule is practiced right after training. Without immediate use the rule will be forgotten or its perceived importance will be reduced.
- Ensure that the rule is applied. There must be monitoring and control over the correct use of the rules in practice. Sanctions should be applied in case of violations to demonstrate that there is a cost for not using the rule.

**Why do people take risks?**

Risks are natural and constant in any activity carried out, regardless of the level of complexity, there is always uncertainty involved, however small, and it is also part of human nature to take controlled risks to evolve, reduce boredom, increase enthusiasm and perspective.

**What affects risk taking?**

Each person deals with risks differently. Usually people try to stay in a comfort zone, taking the risks they know or have experience dealing with. Depending on the situation, due to a feeling of boredom (low exposure to risk) or fear (high exposure to risk) people change the

way they act to give them a feeling of enthusiasm or control. Some people naturally seek higher levels of risk than others. According to Keinan G. Meir E. & Gome-Nemirovsky T. (1984) these people have a specific personality and usually have one or more of the following characteristics.

• Low self-control

• Lack of planning capacity and long-term vision

• Search for emotions

• High self-esteem

• Active person

• Cares more for personal freedom than for living in society

• Need for independence

Regardless of personality and aversion or pretension to take risks, a human problem is that the real risk and the perceived risk differ greatly. Controlling risky behavior is complicated, people usually carry out their activities in a way that they believe to be safe, even if they are not. There are many factors that influence people's perception of risk, so simply showing the risks is rarely as effective as expected. If people are not averse to the exposed risk, it is necessary to use more efficient means within the areas of knowledge of human factors to convince people.

The approaches used to reduce risky behavior are:

- Selection - Tools are used to measure people's propensity to take risks already in the selection process, each type of position requires a risk-related behavior profile. One of the tools widely used is psychometric tests such as the Zuckerman Sensation Search Scale
- Targeted communications - Communication must be carried out according to the profile of people, people with risk aversion are easily impacted by direct communication about risk, risk tolerant people need to see the correlation of risk with personal experiences, risk deniers are not affected communication and risk hunters may even be influenced to seek risk after communication
- Behavior modification programs. - Organizations can use it in a structured way to create a safety culture that shapes the behavior of people involved with the group

**Why do accidents happen?**

*The approaches*

Human errors are closely involved in accidents, but it is recognized that in most cases, accidents are the result of a complex chain of contributory events, and that some of the factors are permanently present in normal working conditions. So the question became "What are all these factors that contribute and how do they all come together at times to create an accident?"

To answer this question, James Reason proposed his now widely known "Swiss cheese" model.

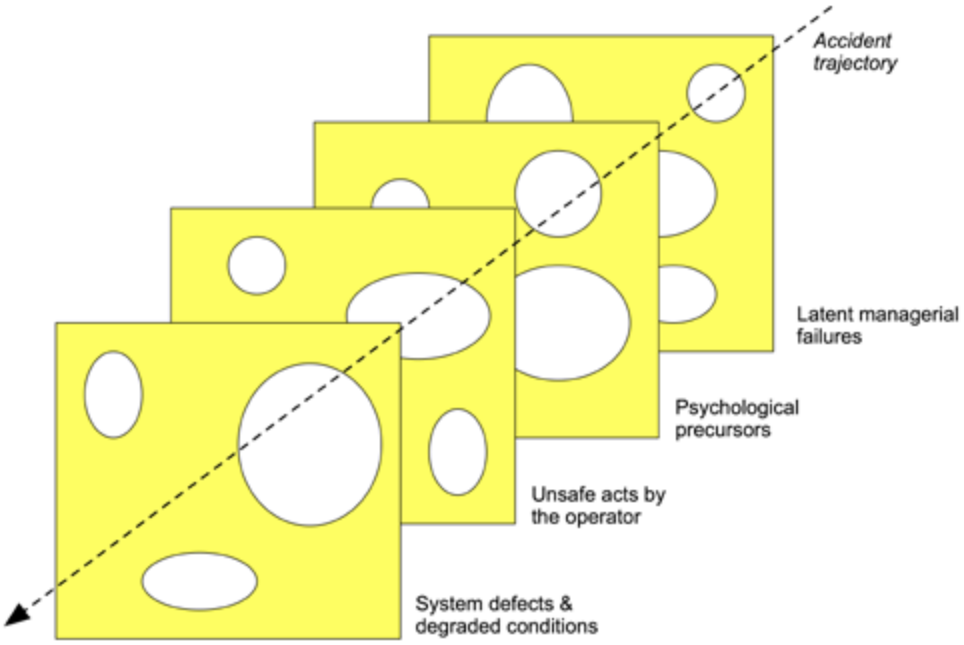



FIGURE 9 - SWISS CHEESE MODEL

Reason's (1990) theory states that systems have multiple layers of defense against dangers and errors. Only when the failures in these defenses align and happen simultaneously does the accident happen. The last line of defense is a person's ability to make up for mistakes

The involvement of a human being is positive for a system in normal operation, but it is a weakness as abnormal or degraded conditions affect the ability to deal with the situation. Qualified and motivated operators are good last-line defenses in adverse conditions, and prevent a bad situation from getting worse. Some of the "holes in Swiss cheese" are related to human performance, and others are "latent" conditions, such as a deficient system or errors in design and procedures. Good measures that reduce “cheese holes” are important to reduce the risk of accidents. The tools presented in this paper from the five critical areas of human performance can help to close these gaps, along with best health and safety and engineering practices. Looking at the past and learning from accidents, identifying the root cause and the complementary causes of failure is also critical. We present some methods, including fault trees and HAZOP. Another important tool for the identification and classification of human factors in this area is the HFACS (System of Classification and Analysis of Human Factors. The structure helps to identify the origin of unsafe acts (error or violation), the boundary conditions of the acts, and helps identify if the individual, supervision or organization failed as shown in the image below:

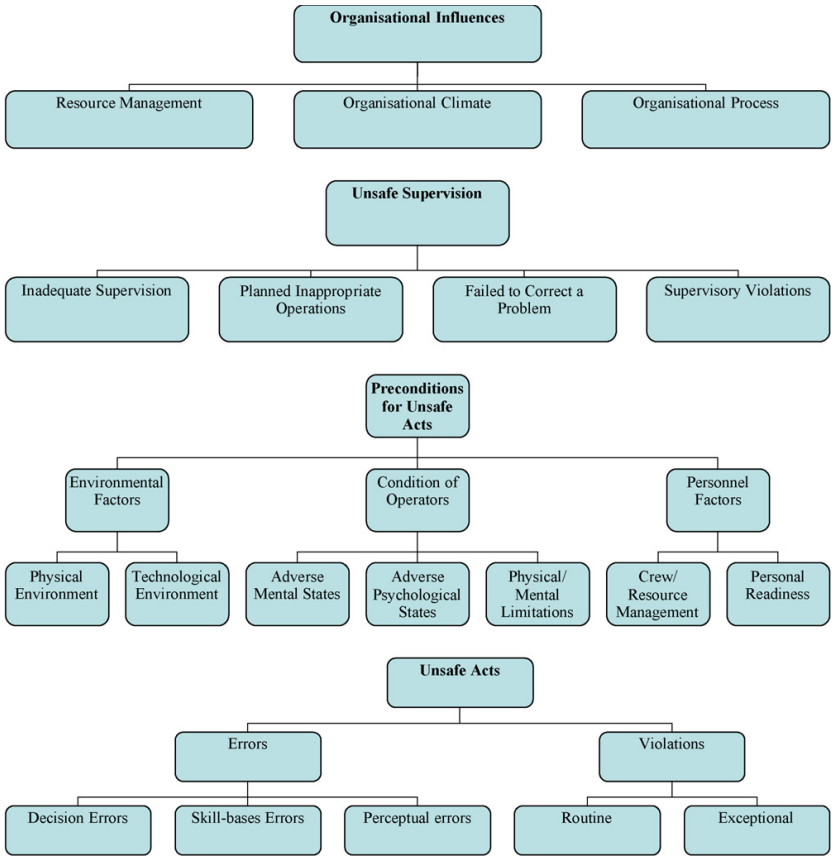
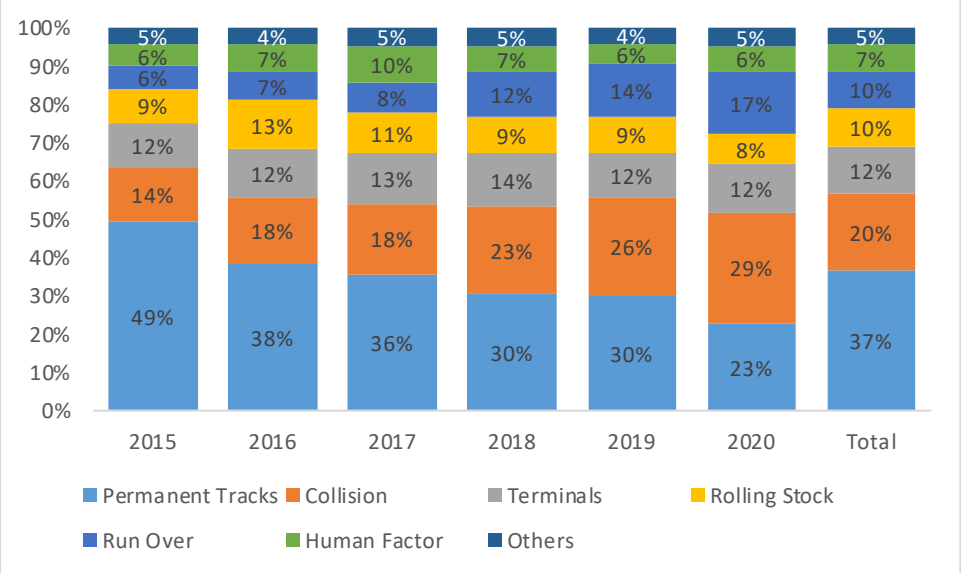



**FIGURE 10 - HFACS TOOL**

# 3 PROBLEM DESCRIPTION

Rumo has a database of all occurrences in its network, since the beginning of the railway's operations. For the purposes of data analysis in this work, the period from 2015 to 2020 will be delimited.

The graph below shows the distribution of the total accidents and occurrences recorded in the period, in the Rumo operations:




GRAPH 8 - ACCIDENTS AT RUMO OPERATIONS SINCE 2015

Of the total number of recorded events, 7% had their investigations conclusive indicating that the occurrence was due to some human factor, either due to technical or physical issues. It is not the factor that causes more accidents in the company, however, all other causes already have exhaustive investigations and treatments to understand and avoid new occurrences. For this reason, it was decided to further study the events caused by human actions.

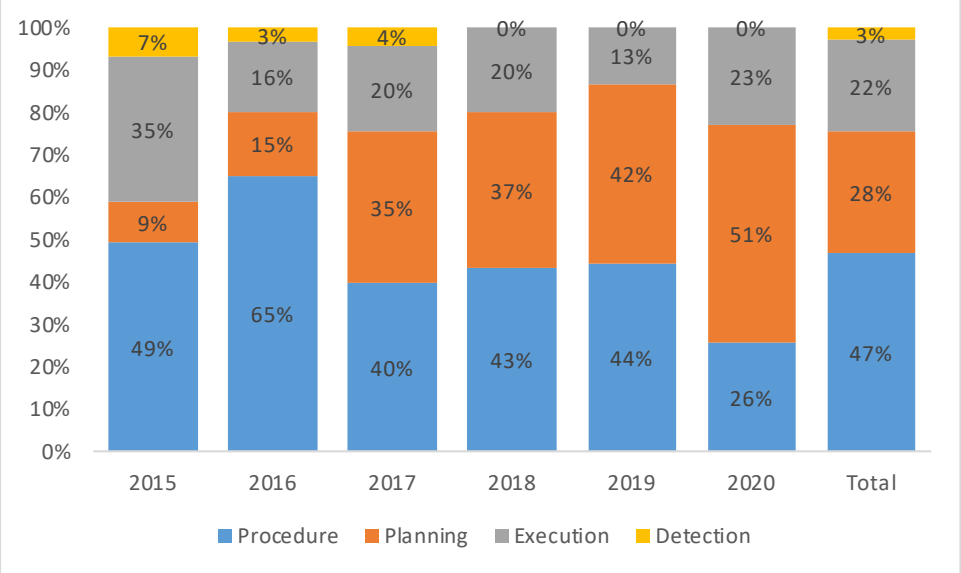
It is not by chance that the occurrences caused by human factors at Rumo have recently been analyzed in greater depth. As of August 2020, the company established a new and structured line of complete and detailed investigation for these occurrences. For this reason, practically all accidents reported in the company's historical database have shallow assessments of accidents caused by human error. Therefore, for the purpose of developing this work, premises will be adopted that will be detailed throughout the document so that the development of the work can occur without major difficulties. It is important to highlight that the premises adopted take into account the experience of years of monitoring railway accidents by the authors of this work.

In order to understand the causes that contributed to the event, the occurrences caused by a human factor must still be classified by the circumstances that led to their cause, with the following factors being listed:

- Detection: The accident occurs because there was a failure to detect a defect, which should have been pointed out by human action;
- • Execution: It occurs because the service was not performed according to established procedures;
- • Planning: It occurs because there was no adequate maintenance planning;

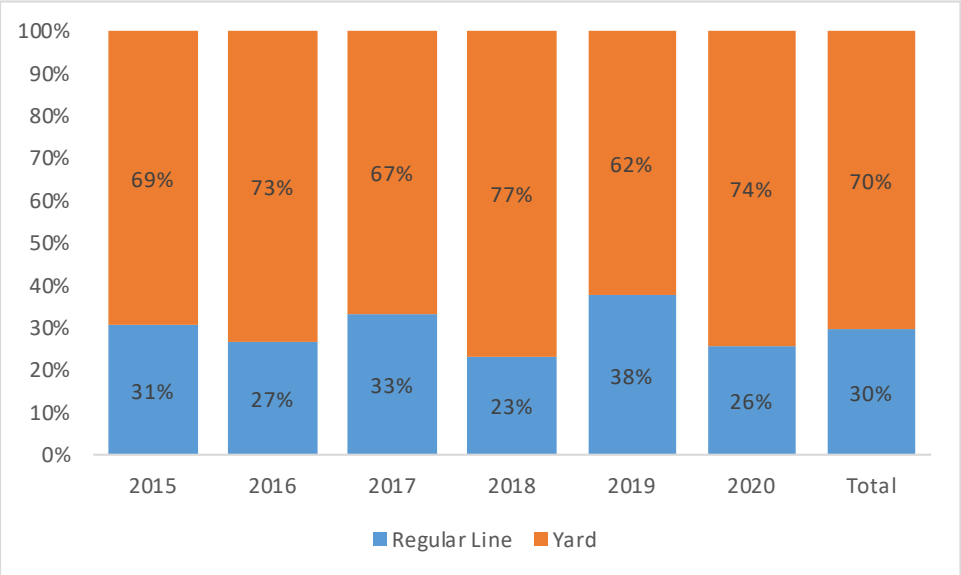
- • Procedure: It occurs when there is no procedure, or what exists is wrong or incomplete.

Highlighting the data in the chart above, listing only the accidents caused by the human factor and, from the classification above, the occurrences caused by the human factor, among the evaluated data, are distributed as follows:




GRAPH 9 - ACCIDENTS CAUSED BY HUMAN FACTOR

Still, it is important to note that the occurrences of accidents caused by human error are, for the most part, events within maneuvering yards, as shown in the chart below.




GRAPH 10 - ACCIDENTS IN YARDS OR REGULAR LINES

In a very specific way, the occurrences caused by problems in execution are directly linked to the moment of the occurrence, as they have less correlation with previous factors such as definition of procedures or planning of the operation. The causes for execution are directly linked to what the operator is feeling when the accident happens, from physical factors such as fatigue, to psychological factors linked to mental health. Therefore, it is

possible to identify causes that, primarily, contribute to the occurrence of the accident, related to the human factor, such as:

- Fatigue
- Inattention related to psychological factors
- Misinterpretation of procedures
- Among others

As shown at the Graph 10 , most accidents occur within maneuvering yards, with 70% of the cases analyzed since 2015 occurring in these locations. Thus, the present work will describe further information on how these accidents happen, as well as explore possible solutions for this type of occurrences to be avoided.

Therefore, as can be seen, accidents and incidents caused by human factors are extremely sensitive for railway operation. Despite the need to mitigate them so that they no longer happen, it is still necessary to evaluate these cases to learn and understand each fact.

Thus, the present work aims to find and propose methodologies or solutions for the preventive treatment of scenarios that may cause accidents due to the human factor.

### 3.1 Real case Analisys

The Graph 8 show that 6% of accidents at Rumo has been caused by human failures.

This work proposes a solution for a specified part of this failures, the operational failures by human error during conducting of the train or in a yard site, that represents the amount of 92,5% from January 2019 until September 2020 of all operational failures (source: internal data).

As shown above, until august 2020 Rumo used a simplified method to analysis human error. The investigation finished when the analyses showed to a human error by mistake or by negligence. However, as shown, human errors are much more complex than this and it also requires a deeper investigation to understand the reasons of the error.

For instance, we investigated a specified accident occurred in March 2020 in a yard site. Figure 10 until Figure 15 represent how the derailment happened step by step.

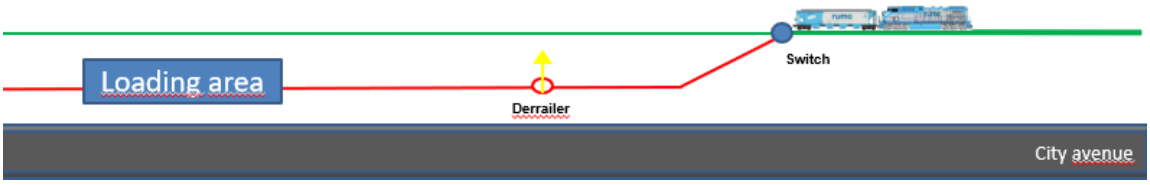



FIGURE 11 - TRAIN STOP AT THE SWITCH TO ACCESS DE LOADING AREA

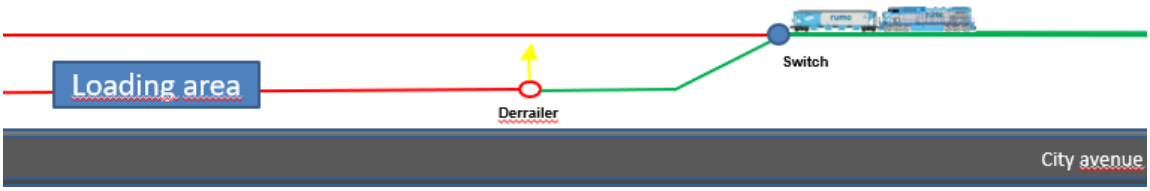



FIGURE 12 - MANUAL SWITCH CHANGE TO THE LOADING LINE


FIGURE 13 – OPERATOR TURNS DOWN THE FLAG AND FORGET TO CHANGE THE DERAILER SWITCH


FIGURE 14 - COMPOSITION PASS THROUGH THE DERAILER ON THE WRONG POSITION, DAMAGING THE EQUIPMENT


FIGURE 15 - DURING THE MANEUVER TO THE MAIN LINE THE LOCOMOTIVE DERAILS ONE WHEEL AT THE DAMAGED DERAILER

This is a classic example of simplified analysis used at Rumo. Although this event happened by human error by negligence, there are a plenty of other reasons that contribute to this. This analysis will show some missing points not observed during the investigation.

To avoid human failures by negligence there is a defined routine that the leadership team must achieve monthly. This routine is controlled by the indicator risk indicator, if it is bellow than 90% means a non-satisfactory result (internal definition) and if it above than 90% means a satisfactory result. Table 2 shows the result of this indicator at previously month before the accident on the site in the example. The result of 67% showed that routine wasn´t achieved well. So, this is also another factor that could contributed to the event.

| rumo | | XXXX |
|---|---|---|
| | | Yard |
| Yard´s failure | Result | 100% |
| Operational management | Result | 33% |
| Training Schedule | Result | 100% |
| General Result | | 67% |

TABLE 1 - FEBRUARY RESULT OF RISK INDICATOR

*Source: Authors.*

Another important factor is to analyze the conditions on site in this event as local luminosity, organization of area and operator equipment. Figure 15 and Figure 16 show the site at the occurrence time. It is perceptive that the general organization aren´t the ideal. There are excess

of bush and lack of proper identification at the switch. These conditions also can contribute to the failure.


FIGURE 16 - EXCESS OF BUSH AT THE DERAILER REGION

FIGURE 17 - LACK OF PROPER IDENTIFICATION AT DERAILER AREA

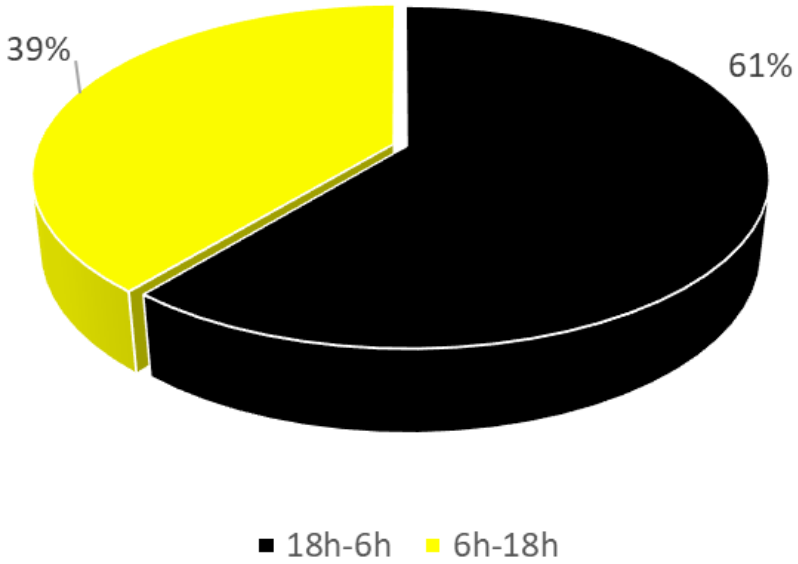
The derailer has an interlock system, when the derailer´s flag in vertical way means that the derailer is to derailment position. This equipment wasn´t work in that condition. There was a maintenance order at the time to repair that function.

Another point to observe is the equipment condition. The locomotive involved in the derailment is a G12 model locomotive. This is an equipment from 1950 decade, it has the operational cab in the middle of the locomotive and it also has a limited vision field at driver position. Figure 18 and Figure 19 show the vision field in this locomotive model.


FIGURE 18 - EMD G12 LOCOMOTIVE - DRIVER´S CAB IN THE MIDDLE OF THE LOCOMOTIVE

Figure 19 - Vision field at driver position

Another important point of view is the occurrence time. 61% accidents of switch in the wrong position happened at night and most of them happened in sites that didn´t have a properly luminosity. Of course, this is not the only reason of accidents during the night. We also must observe some human limitations as fatigue, discussed in chapter 2.




GRAPH 11 - SWITCH IN WRONG POSITION DERAILMENTS BY TIME - RUMO - 2019

*Source: Internal data*

As previously example site conditions, fatigue, leadership routine, properly training and other points are important points to investigate during a human error accident analysis.

### 3.2 Cost of Accidents

We have seen that accidents caused by human errors are extremely damaging to the railway operation and that, despite this, they have not yet been deeply studied by Rumo for its dealings. Furthermore, the way in which they occur causes the operation to suffer too much from unscheduled downtime and corrective maintenance both in permanent and rolling stock.

However, it is important to note that all these events still generate undesired costs, which were not foreseen by the company, causing impacts on Rumo's budget and financial results.

Internal data show that accidents that have occurred within maneuvering yards since 2015 have already cost the company almost BRL 11 millions, being the average BRL 1.8 millions per year. Each recorded occurrence has an average cost almost BRL 40 thousand, which causes significant damage to the company's budget management.

Therefore, this work should show, as will be discussed below, proposals and ideas to make the operation increasingly safe so that accidents caused by human error are increasingly rare in the operation of the railway.

## 4 HAZOP IN HUMAN ERRORS ACCIDENT

This project used the HAZOP methodology to identify the lack of possibilities as showed in chapter **3.**.

TABLE 2 - HAZOP ANALYSIS OF HUMAN FAILURES IN SWITCH OPERATION

| Deviations | Possible cause | Consequences | Safeguards | Risk Matrix | | | Recommendations |
|---|---|---|---|---|---|---|---|
| | | | | P | I | T | |
| Vegetation at the site | Lack of proper maintenance | Make difficult to check the switch position | Operator check at site | 1 | 2 | 3 | To reduce the period between weeding maintenance. To study the use of chemical products to eliminate the bush |
| Little lighting | Lack of proper illumination | Make difficult to check the switch position | Use of flashlight | 1 | 2 | 3 | To install spotlights nearly switches. To study use of powerful headlights. |
| Limited field of vision | Old layout equipment | Reduction field of vision to the driver | Operator check at site | 2 | 1 | 3 | To study driver cab change to the front part of locomotive. To study use of cameras to increase vision field of the driver. |
| Inappropriate leadership inspection | Full schedule Human behavior | Make difficult to identify and to correct human errors | | 2 | 2 | 4 | Review of leadership schedule to focus on site inspections |
| Derail position flag without interlock | Lack of proper maintenance | It allows the switch in the derail position without proper indication | Operator check at site | 1 | 3 | 4 | Use maintenance management system to control yard ‘s switch repairs |
| Inappropriate training management | -Ineffective control system -Online Trainings without check of knowledge | Make difficult to check training schedule and to check the effectiveness of training | Monthly General Test | 1 | 3 | 4 | Requires that online or presential trainings have a test to check if the training achieve the expected |
| Inappropriate accident analysis method | | Non identification of contributing causes | - | 3 | 3 | 6 | -Use of HAZOP methodology to analyze process related to accidents |

To prioritize the actions to mean causes, the authors of this study develop a matrix at Table 3. This work will analyze deviations above 4 in risk matrix at Table 3.

Once major accidents classified as human factor cause happens in shunting yards, as a complement of the Hazop mentioned above, the next figure shows an exercise using Cause and Effect Analysis Methodology related to our main problem: derailments in shunting yards. With this analysis, we could realize that each primary cause is related to the “Performance 10 Incident Factors” and some important outputs were defined, which could

be classified as process problems, infrastructure problems and training system. The idea and focus of this Project is to propose some technologycal approach to be developed and help to mitigate some of these problems.

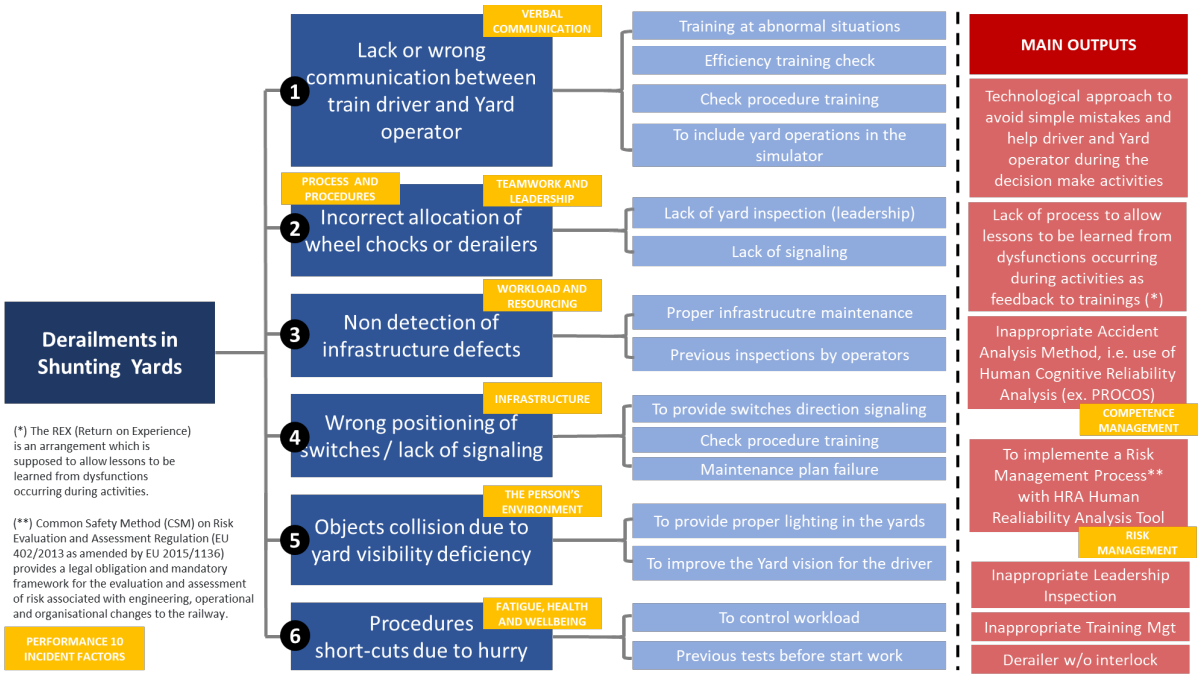



FIGURE 20 - CAUSE AND EFFECT ANALYSIS (DERAILMENT IN SHUNTING YARDS)

Complementing this analysis, follow the main proposals considered in this study. We were already careful to check the connections of our proposals with the Critical Areas of Human Factors, its main classical erros management and topics to be evaluate as presented during one of the modules of the DB training. All proposals are valid and important to be implemented in our company, but as we mencioned above, we developed and discussed in more details only the technologycal (highlighted) ones.

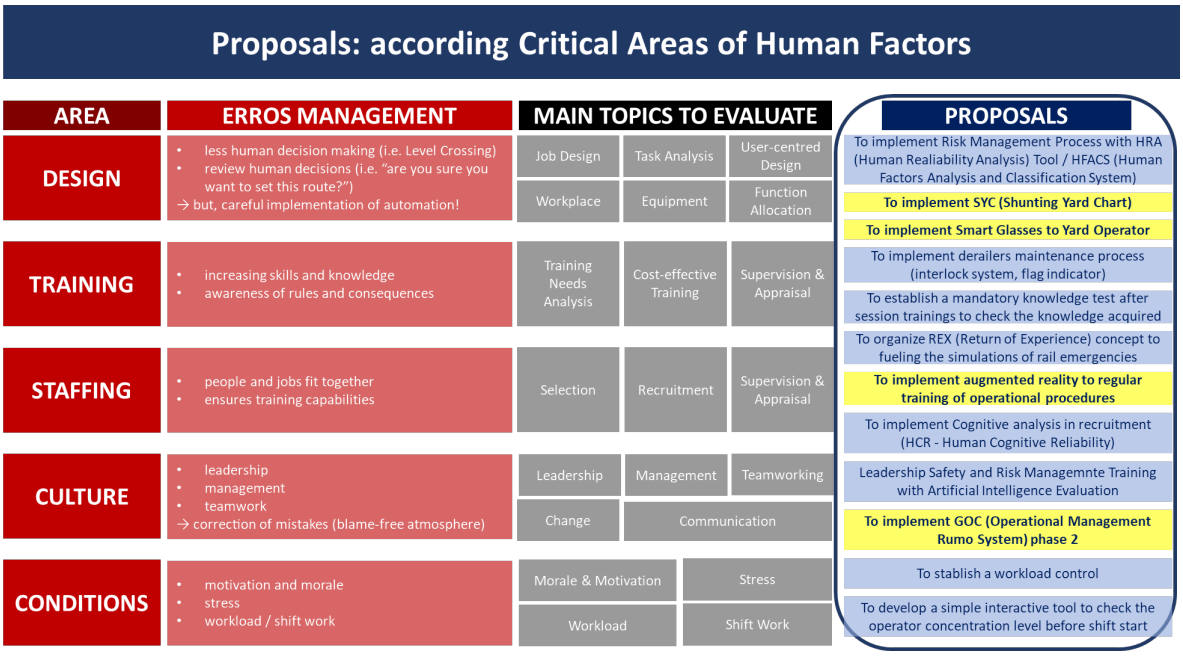



FIGURE 21 - MAIN PROPOSALS TO DEVELOP AND MITIGATE HUMAN ERROR (DERAIL IN SHUNTING YARDS)

Following the details of each proposal choosed as focus of this project.

### 4.1.1 SHUNTING YARD CHART

Currently our freight operation shunting yards are not properly automatized with the “best in class” and known classical railway solutions as electrical switches, signaling and safety interlocks, which could avoid many risks regarding communication problems between driver and yard operators.


FIGURE 22 - RUMO’S SHUNTING YARD INFORMATIONAL BOARD (EXAMPLE)

Once this kind of solution is very expensive and a long term investment, the idea is to develop a suitable, viable and cheaper solution to mitigate this kind of risk through the implementation of an interactive and “live” yard panel / synoptic (SYC – Shunting Yard Chart) that could inform all yard occupations and switches position once the operator moved them, even if manually. All these yard informations will be informed by the operator in a mobile device and automatically updated at locomotive and station panels.

Besides that, the supervisory will have an intelligence capable of launching risk alerts depending on the position and direction of the train.

In addition, we are developing an electric limit switch /sensor solution to indicate the switches position and connected with the chart.

Below we have a schematic example of the panel idea.

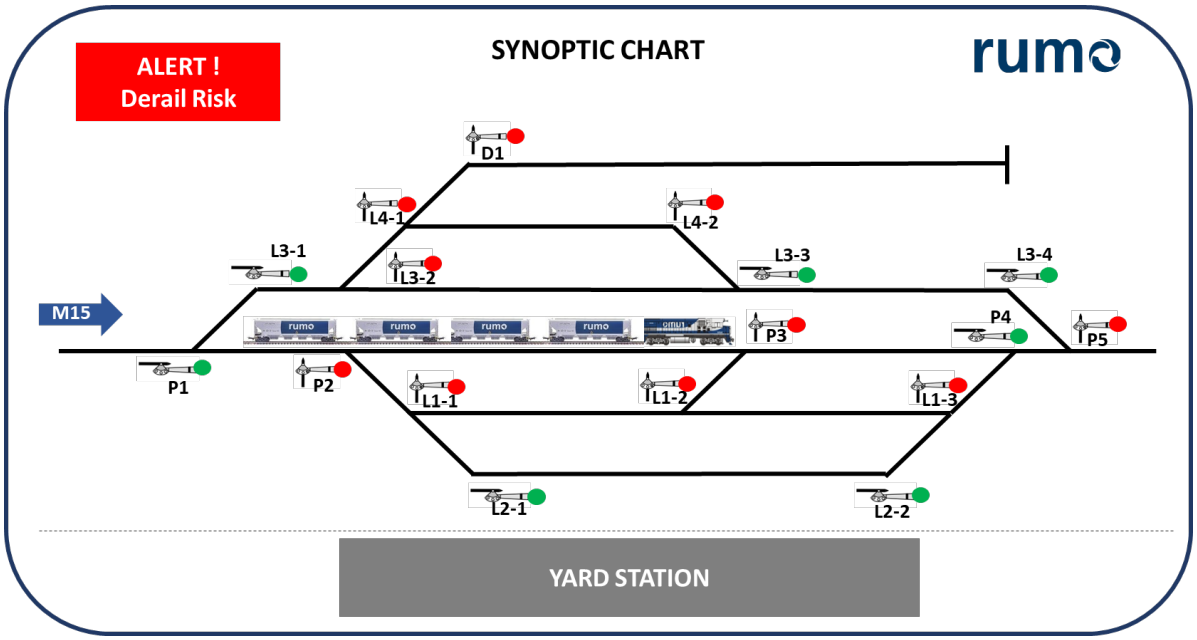



FIGURE 23 - SHUNTING YARD CHART (SYNOPTIC EXAMPLE)

### 4.1.2 USE OF SMART GLASSES FOR "PUSH BACK" YARD OPERATIONS

One the most critical operations at the yard is the "push back" due to the risk of collisions.

In this kind of shunt the train driver is not visualizing the end of the train and will have to fully believe the information from the yard operator. If the operator makes a mistake or some audio communication misunderstanding, the risk of an accident is very high.

To avoid this kind of situation, the idea is to implement the use of smart glasses for yard operators. Once the operator is always in the end of the train in this shunt operation, all his visualization can be replicated to the train driver and yard station as well due to a fixed camera integrated to the smart glasses.

Another important feature of this device is to allow fully audio communication between driver and yard operator with hands free besides receiving procedures, tasks, orientation images that can be visualized in glasses.

FIGURE 24 - SMART GLASSES EXAMPLES

### 4.1.3 INAPPROPIATE LEADERSHIP INSPECTION

In a company, managers are the key piece for the operation of the sectors. It is up to the company's leadership to hire and training employees. This sector is also responsible for establishing good communication between all team members, a fundamental requirement to ensure the control of occupational risks and the prevention of work accidents that may compromise the physical integrity of workers. In addition, the company's leadership should serve as an example for all employees and act with them in the construction of a safe work environment.

Table 2 shows that the leadership performance wasn´t well at previously month before the derailment. This factor can be also analyzed using the HAZOP methodology. The authors will propose some actions to help and to capacity local leadership to keep then focus on management schedule:

a- Implementation of phase 2 of management system GOC (Operational management Rumo system). This system will allow local leadership to check and to control their routine online by using any smartphone This system will reduce the administrative time of leadership job, allowing more presence in the site. This system will allow the local leadership knows which professional of his team that doesn´t pass by some inspection in the current month for instance with few tips on a smartphone. Of course, this system has other important functions as employee record, training schedule and month technical tests results.
b- Implementation of a corporative program of leadership development. This program will allow leadership to know his team better and to discover the main characteristics, expectations and motivational needs of professionals from different generations, learn how to identify and enhance the best of each and how to increase collaboration between them. To Find out what mental triggers are and how to use them with each employee on your team and learn how to be a more influential leader for your team. To understand the difference between feedback and feedforward and learn how to give feedback assertively so that they generate results and desired behavior changes.
c- To define the ideal leadership profile and use this as a selection criterion to new leaders. A leader needs to know how to motivate, involve the team, pass knowledge, follow the evolution of people, point out failures of their team so that they are improved, resolve conflicts, among other activities of great responsibility.

### 4.1.4 DERAIL POSITION FLAG WITHOUT INTERLOCK

Poka Yoke. This name, so curious, is of Japanese origin and means "error-proof". From there, you can already get an idea of the nature of this tool, which was created in Japan and deployed in the Toyota Production System for some time now. Yes, the name may be funny, but the function of Poka Yoke is very serious: it is an inspection system developed to prevent risks of human failures and correct any errors in industrial processes, always through simple actions.

An interlock system can be considered a Poka Yoke equipment. One of the causes of derailment analyzed in chapter 4 is the lack interlock system on the derailer. It allowed the operator turned down the indicator flag even with the derailer on the derailment position. It was an undesirable condition. The authors suggest following the recommendation bellow:

a) To check all derailers and generate maintenance order to repair those haven´t the interlock system working properly.
b) To standardize the flag indicator with interlock system, including this in technical specification of derailer.


FIGURE 25 - DERAILER AND FLAG OF SWITCH ON DERAILMENT POSITION

### 4.1.5 INAPPROPRIATE TRAINING MANAGEMENT

Low productivity, accidents at work and other factors that contribute to the losses in companies can be solved with investment in certification and training of people.

Currently Rumo's operational procedures training is mostly in online format and 92% of them do not have a check test to validate the acquired knowledge.

In the railway operation conducting practical training can be a great difficulty due to the need for large sites to simulate operational environments and in extensive geographic companies as the case of Rumo would need several training sites to meet the needs of each site or have a high cost of travel to bring employees to a centralized site. To solve this problem, solutions such as augmented reality are pertinent paths to follow.

Hands-on training can be applied through virtual simulators. With the possibility of creating specific scenarios and conditions, including with different levels of difficulty, the simulators allow a high degree of immersion of employees in a practical and very realistic training. They are focused on the development of expertise on the equipment and processes. All this without risk of accidents and without having to stop production for training in real equipment.

The authors suggest 2 solutions to increase the method of training in operational sites at Rumo:

a) To establish a mandatory knowledge test after online session trainings to check the knowledge acquired.
b) To study the implementation of augmented reality to regular training of operational procedures.

### 4.1.6 INAPPROPRIATE ACCIDENT ANALYSIS METHOD

The Hazop, from the Hazard and Operability Study is a systematic way to identify possible hazards in a work process, dividing it into stages and considering variations in work parameters for each, to see what can go wrong.

The authors suggest the use of a HAZOP methodology to analyze the process related to derailment events at Rumo, for instance the short analysis of wrong switch operation discussed chapters 3 and 4.

### 4.1.7 VIRTUAL REALITY

The use of virtual reality systems for simulation is a tool that allows to increase the productivity of the processes of movement and transport of materials. In this environment the dynamic behavior of the handling equipment is simulated in real time, allowing the operator training increasing its efficiency. Virtual reality systems for simulating operator handling and training equipment, have computers working interconnected in a network architecture allowing to increase processing capacity and maximizing the efficiency of information exchange between system modules, and constitutes a complete basis to emulate all operational aspects of the system through consoles, panels and computer displays. Depending on the type of application the system can contain the dynamic model of the system and its drive, drive and interaction sub-systems. The movement, sound and visualization of the environment should allow the total immersion of the user and greater proximity to reality. All these features must be calculated in real time during simulation which requires high computing capacity. Developments of this nature allow the consolidation of equipment knowledge and meet the needs of industry and operators in the management of technical knowledge of handling systems, constituting a virtual tool for training operators seeking to increase performance. The process of development and innovation of virtual reality systems consolidates and improves the knowledge sensitive to this specialty, allowing to achieve and scientific competence necessary for the field of technique. In this way companies that seek efficiency in production can benefit from this technology in the pursuit of operation excellence (SOURCE: http://www.usp.br/ldsv/wp-content/uploads/2016/09/EncontroFerrovia_SIM_USP_10r.pdf).

Currently there are several virtual reality solutions in the most diverse segments of the industry, including in the railway industry. To increase the effectiveness of training, the authors of the study propose the use of virtual reality technology for training of patio teams in operational risk situations, which have a high chance of causing an accident. Figure 25 and Figure 26 show a real simulator of Union Pacific, used to training staff at yard operations.

FIGURE 26 - RAIL YARD TRAINING SIMULATOR FROM UNION PACIFIC(1)

Source:
https://www.uprr.com/newsinfo/releases/attachments/2009/simulator_movies_640.mp4

FIGURE 27 - RAIL YARD TRAINING SIMULATOR FROM UNION PACIFIC(2)

Source:
https://www.uprr.com/newsinfo/releases/attachments/2009/simulator_movies_640.mp4

### 4.1.8 IMPLEMENTATION OF GOC PHASE 2

The GOC is a system used by Rumo that supports the base team's leadership routine of the railway operation area, for example first-level leaders, train drivers and yard operators. This system is the basis of the operational management system, it also allows to consult the profile of employee, such as behavioral occurrences, record of incidents, training´s register and it allows the analysis of train conduction to verify the driving mode. Currently this system requires the input of data manually, through the typing of documents and this activity is carried out by the leadership of the base teams. It is estimated that about 40% of the leadership time load is used for administrative routines, among these routines the input of data in the GOC system. There is already identified the need to upgrade the GOC system, for instance to eliminate the need of forms. Another important function is the possibility to consult all information in a real time by using any smartphone. Data input will be online, without use forms or any kind of tipping service. These implementations will allow the leadership to be more present with their teams.

### 4.1.9 IMPLEMENTATION AND FINANCIAL PLAN

For the implementation plan, feasibility analysis and financial of the project, it has been made initial estimates with technology experts from RUMO SA, the initial expectation of implementation among the initiation, execution and control and closing stages is one year, and the expected return it is a 50% reduction in accidents caused by human failures, generating an estimated return of R$ 900,000.00 per year. An estimated cash flow for 10 years was set up and the estimated net present value was R$3.725.442,42 at a discount rate of 7%, and the internal rate of return is 37%, showing that the project has financial viability. Below we show the initial expectations of the implementation and financial plan with the statement of cash flow, NPV and IRR calculated

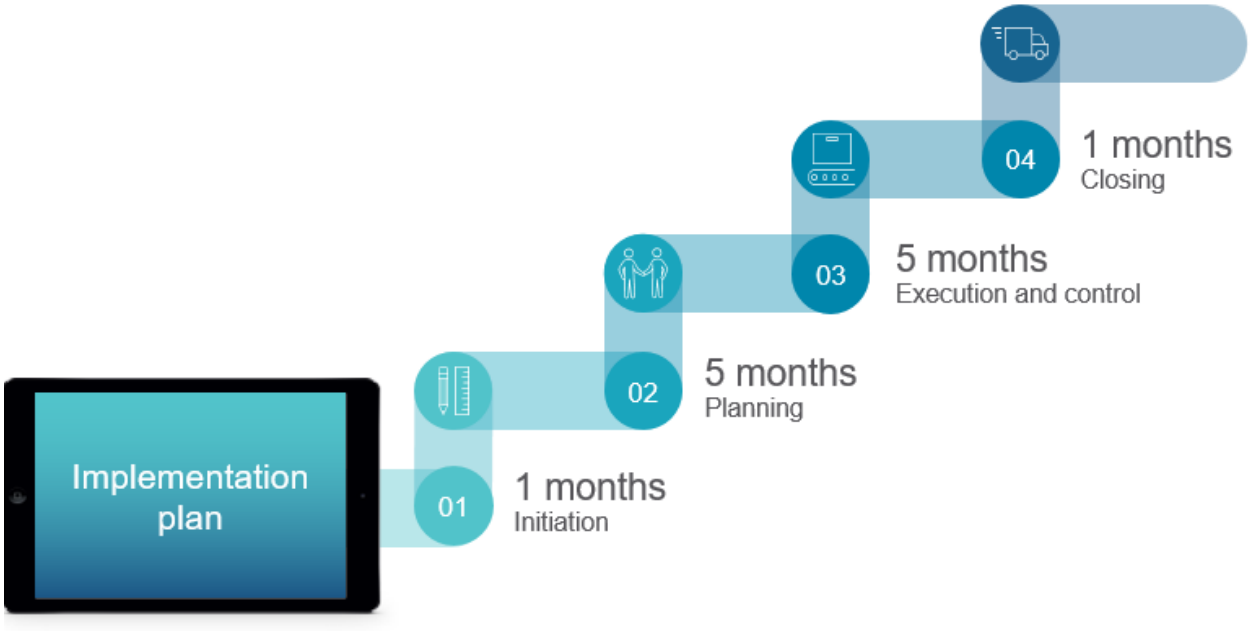



FIGURE 28 - IMPLEMENTATION PLAN

| | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenues | R$ 0 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 |
| Smart Glasses | -R$ 716.000 | | | | | | | | | | |
| Synoptic SY | -R$ 1.350.000 | | | | | | | | | | |
| Virtual reality | -R$ 219.000 | | | | | | | | | | |
| GOC Phase 2 | -R$ 50.000 | | | | | | | | | | |
| free cash flow | -R$ 2.335.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 | R$ 900.000 |
| Discount rate | 7% | | | | | | | | | | |
| NPV | R$ 3.725.442 | | | | | | | | | | |
| IRR | R$ 0 | | | | | | | | | | |

TABLE 3 - FREE CASH FLOW PLAN

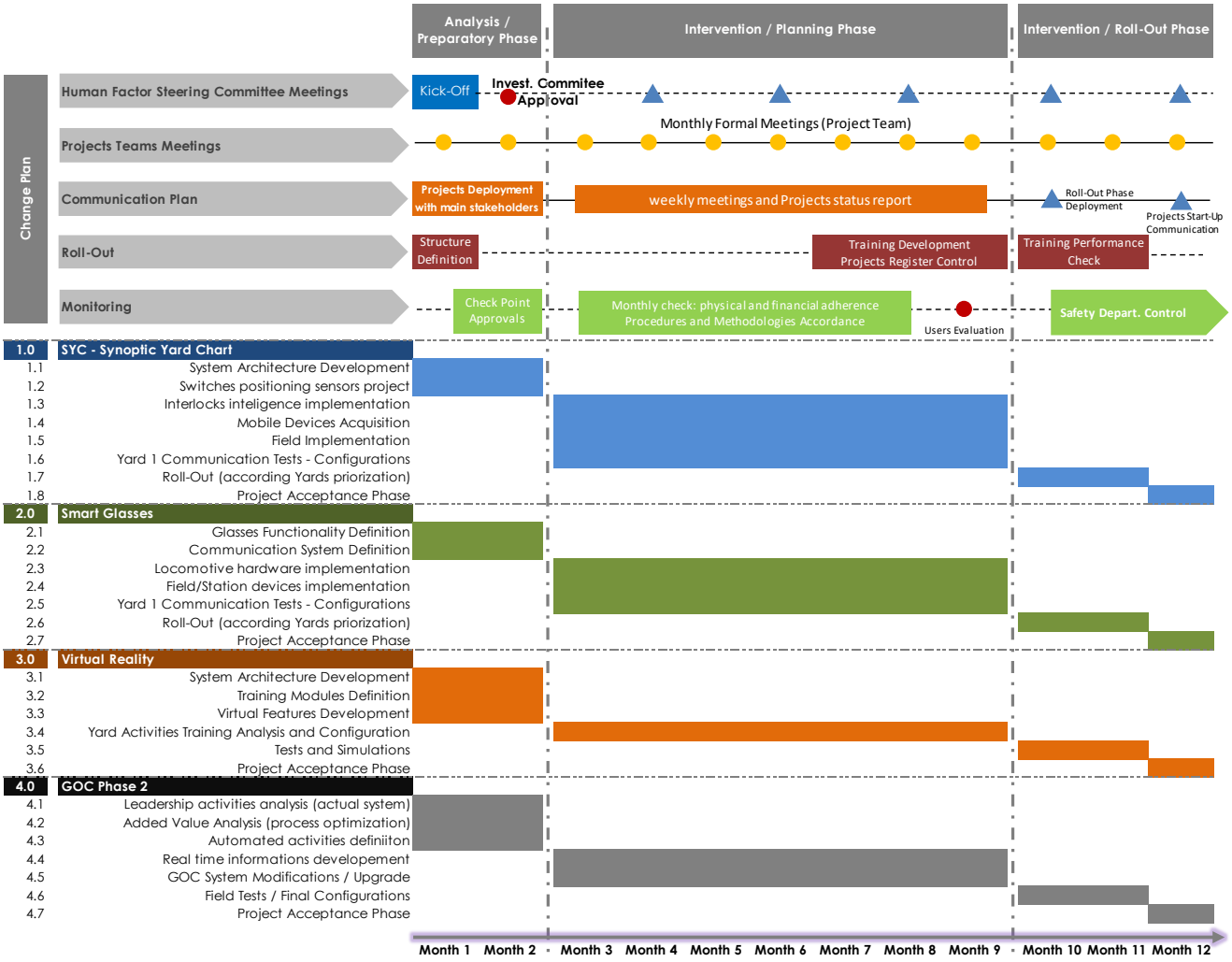



FIGURE 29 - DETAILED PROJECTS IMPLEMENTATION PLAN AND CHANGE PLAN

## 5 CONCLUSION

This work had the objective of presenting possible solutions, directed to the technology area, for the reduction and mitigation of railway accidents caused by human factors.

After a brief assessment of the Brazilian rail transport sector and a robust bibliographic review, seeking information from several areas of knowledge so that the causes that lead railway workers to practice incorrect procedures, causing accidents, can be found, technological solutions were sought for mitigate these causes.

The work sought to propose existing solutions in the market, adapting the technologies already applied in different sectors to the reality of the railway, as well as innovative ideas were proposed to try to reach a new level of railway safety, using the best engineering and technology techniques possible .

At first, the possibility of creating a System yard chart (SYC) was presented, which could automate and identify possible accident risks through actions taken by operators linked to the maneuver.

Then, other solutions linked to augmented reality would be able to make more information available to the actors involved in the operations, so that this information would be used in decision making, reducing the chance of human errors in the operations. Similarly, the

possibility of using the virtual reality technique to simulate handling equipment and operator training was highlighted, whose benefits are evident due to the facilities and advantages they offer in complementing the available training and engineering resources. It is not intended to replace traditional training methods, but only to complement them with visual and interactive resources, providing agility, flexibility and attractiveness to users.

Subsequently, the importance of implementing the second phase of a System that is being developed by Rumo itself, the GOC-2, was discussed, which will act automatically in obtaining the results of evaluations and tests, eliminating manual data entry processes and reducing the time that the manager needs to stay in the office for such activities, being able to be closer to the field activities.

Finally, an assessment of the risks of implementing these solutions was presented, and it was observed that the expected gains from the reduction of accidents caused by human factors exceed the possible risks.

Therefore, this work demonstrates that the adoption of technologies that act in favor of railway safety will never be too many, even if they have a cost for their implementations, these will always bring a safe environment for the company and, mainly, for its employees. In a potentially safe environment, both the company and the employee work with enthusiasm, generating better results and providing better solutions for the country's logistics.

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