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Reduction of Normalization of Deviation (NoD) Using a Socio-Technical Systems Approach

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ABSTRACT

Normalization of deviation (NoD), also known as normalization of deviance, is the process in which deviations from correct or proper decisions, behaviors, or conditions important for safety insidiously become the accepted norm over time. NoD is a common, risky, yet elusive issue causing or contributing to numerous accidents in multiple industries. Effective reduction of NoD is therefore a major opportunity. Approximately 10 years ago, Boeing developed a general systemic model of NoD based on a socio-technical systems approach. It is a representation of how multiple internal and external factors inherent to socio-technical systems interact in a dynamic fashion leading to NoD. It holistically captures the essence and complexity of the problem. The model has been shared across Boeing and with three customer airlines of Boeing. Specific systemic models of NoD associated with specific problems were developed based on the general systemic model. Subsequently, NoD awareness training, methods, tools, processes, and solutions based on those models have been developed. They were provided and/or used to improve workplace safety at Boeing and aviation safety at one of the three airlines. All the efforts have resulted in unprecedented insights, and some have seen significant reduction of NoD, NoD-related incidents, and NoD-related safety risks.

INTRODUCTION

Professor Dianne Vaughan, a sociologist at Columbia University, coined the term of normalization of deviance (Vaughan, 1997). It is also known as normalization of deviation (NoD). She described NoD as a situation where "...people within the organization become so much accustomed to a deviant behavior that they don't consider it as deviant...The more they do it, the more they get accustomed" (Vaughan; see Consultant, 2008). NoD is a common, risky, yet elusive issue having caused or contributed to numerous accidents in multiple industries. For example, NoD was a major factor that contributed to both the Space Shuttle Challenger disaster (Vaughan, 1997) and the Columbia disaster (Columbia Accident Investigation Board, 2003). As another example, "On May 31, 2014...a Gulfstream Aerospace Corporation G-IV, N121JM...crashed after it overran the end of runway 11 during a rejected takeoff...before initiating takeoff, the pilots neglected to perform a flight control check that would have alerted them of the locked flight controls...the pilots had neglected to perform complete flight control checks before 98% of their previous 175 takeoffs in the airplane, indicating that this oversight was habitual and not an anomaly" (National Transportation Safety Board, 2015, p. vii). Given the commonality, the high risks involved, and the elusiveness, effective reduction of NoD is a major opportunity

This paper is a summary of how Boeing developed a general systemic model of NoD, how it has been shared across Boeing and with several customer airlines of Boeing, how a number of specific systemic models of NoD associated with specific problems were developed, how risk mitigation solutions have been implemented within Boeing and one of the airlines, along with the insights and impact that those efforts have resulted in. There have been many Boeing projects or efforts devoted to reducing NoD, and only some of them are reported in this paper.

DEVELOPMENT OF A GENERAL SYSTEMIC MODEL OF NOD

Since the publication of Professor Vaughan's book (Vaughan, 1997), much attention has been paid to the problem across the industries and the academia—at the time of writing this paper, Google searches after entering "normalization of deviance" and "normalization of deviation" yielded approximately 1.22 million and 1.94 million results, respectively. Approximately 10 years ago, we started to develop a general systemic model of NoD based on a socio-technical systems approach after a comprehensive and thorough review of the literature related to NoD. Over the last few years, the model has been updated through several iterations. The model reflects the following characteristics of NoD causation:

- Often, NoD is caused by complex non-linear interactions among multiple factors inherent to a socio-technical system such as a manufacturer and an airline. Those factors are human, technical, environmental, organizational, and external factors. As a part of the human factors involved, cognitive biases (in particular, complacency) play an important role in the NoD causation.
- Further, the systemic NoD causation evolves over time. For example, if the first-time deviation does not cause an accident, it may reduce the perceived safety risk leading to another deviation, which may further reduce the perceived safety risk if there is still no accident yet.
- The process is insidious. That is, typically the problem develops gradually with a long period of time between the first deviation and a tangible consequence.

The model is a general model because it captures the essential characteristics of the NoD causation that are applicable across multiple situations and circumstances across multiple industries. Because the model is a representation of how multiple factors inside and outside a socio-technical system interact with each other causing the NoD problem, it is also a systemic model. It follows that because of the systemic nature of NoD causation, there need to be systemic solutions addressing multiple factors instead of only one solution focusing on one factor. For example, making workers and managers aware of the safety risk involved in NoD alone may not be sufficient to stop NoD if other factors (e.g., rewarding individuals that exhibit the NoD behaviors) are still contributing to the problem.

SHARING OF THE GENERAL SYSTEMIC MODEL OF NOD

Over the last few years, the general systemic model of NoD has been shared and the systemic NoD reduction solutions have been advocated across multiple Boeing business units, functions, and executive levels, as well as the Boeing technical fellow community and many other parts of the Boeing workforce. Training has been provided in many organizations at Boeing on the general systemic NoD model and the systemic NoD reduction solutions. Highly positive feedback has been received. For example, many indicated that the training was among the best provided from the perspective of Go for Zero, which is Boeing's initiative to significantly improve workplace safety. Further, multiple courses on the model and systemic solutions have been developed and taught at Boeing.

Under customer services general terms agreements (CSGTAs), the general systemic model of NoD has been shared with three airlines in the form of presentations and training. Pilots, mechanics, safety analysts, managers, and other personnel in those organizations have benefited from the knowledge. The knowledge sharing with one of the airlines is part of a collaborative project with the company (see the next section of this paper for more information regarding the project).

DEVELOPMENT AND APPLICATIONS OF SPECIFIC SYSTEMIC MODELS OF NOD

Based on the general systemic model of NoD, a number of specific systemic models of NoD were developed such as those associated with disuse of material handling equipment (MHE) at Boeing, landings outside touchdown zones at an airline, and continuation of unstable approaches at another airline. Then, NoD awareness training, methods, tools, processes, and solutions were developed. They were provided and/or used to improve workplace safety within Boeing and aviation safety at one of the three customer airlines. It needs to be noted that which of them were provided and/or used depended on the specific NoD problems that needed to be tackled; that is, not all of them were used for every NoD reduction project or effort.

IDENTIFICATION OF FACTORS LEADING TO NOD IN DISUSE OF MATERIAL HANDLING EQUIPMENT (MHE)

Use of MHE is a proven way to prevent ergonomic injuries. However, MHE in some of Boeing's manufacturing processes was not used under some circumstances leading to NoD, contributing to accidents and injuries. Disuse of MHE occurred more often on some programs than in others. A specific systemic model of NoD associated with disuse of MHE was developed. It was then used to guide the identification of the factors that caused and contributed to the NoD problem. Unprecedented insights were revealed regarding how multiple factors interacted with one another in a dynamic and complex manner leading to the NoD problem.

MITIGATION OF RISKS FROM NOD ASSOCIATED WITH HUMAN-ROBOT INTERACTIONS

This project examined how human operators interacted with robots, which were deployed to assemble fuselages. The human operators needed to "monitor" and "supervise" the robots. Observations and interviews were conducted to collect data as to whether and what factors might cause NoD from operating procedures. A specific systemic model of NoD was developed based on the data. Similar to the MHE study outlined above, insights were discovered as to what caused the NoD, how, and why, much of which were not available previously. Subsequently, multiple solutions guided by the model have been implemented and results have shown significant reduction of the NoD beyond those by using traditional methods.

NOD AWARENESS TRAINING, NOD SURVEYS, AND NOD CHECKLIST FOR REDUCING NOD AND NOD-RELATED WORKPLACE INCIDENTS

In 2018, a Boeing NoD reduction project team collaborated with five different work teams at Boeing. First, the project team provided NoD reduction training to the five teams including an introduction to a NoD checklist, which was developed based on a specific systemic model of NoD. Right after the training, the five teams participated in a NoD survey (based on the same specific systemic model of NoD), which baselined any potential existing NoD behaviors in the teams and whether multiple factors (other human factors, technical factors, environmental factors, organizational factors, and external factors) contributed to NoD. The baseline was designated as the "before use of checklist" time period. The project team analyzed workplace incident data from the five teams associated with the "before use of checklist" time period to identify how many of the incidents or near misses involved NoD. The five teams then used the NoD checklist for approximately one and half months. After this time passed, the five teams participated in a second NoD survey related to the "after use of checklist" time period. Then the project team analyzed workplace incident data from the five teams associated with the "after use of checklist" time period. The survey results indicate that the "after use of checklist" NoD behaviors reduced compared to the "before use of checklist" NoD behaviors, so did contributions to NoD from the multiple factors. The results of the workplace incident data analysis show that the number of "after use of checklist" incidents or near misses involving NoD has also reduced relative to the "before use of checklist" ones.

In 2019, two teams (different from those five in 2018) participated in a NoD survey. Data were collected and analyzed. Solutions, including systemic NoD reduction training and use of a systemic NoD reduction checklist, were implemented. In 2020, five additional teams participated in the survey. Data were collected and analyzed and solutions were implemented. The NoD surveys deployed in those projects were part of assessment of a negative safety culture, which complemented assessment of a positive safety culture.

ANALYSIS OF RUNWAY OVERRUN RISKS FROM NOD IN LANDINGS OUTSIDE TOUCHDOWN ZONES

Globally, landing accidents made up 26% of fatal accidents from 2011 to 2020. NoD has been involved in a major type of landing accident—runway overruns. Percentage of landings outside touchdown zones was used as a key indicator of actual runway overrun risks at an airline. The green oval and the red oval in Figure 1 illustrate landings inside and outside touchdown zone, respectively. A specific systemic model regarding NoD involved in the landings outside touchdown zones was developed and six hypotheses based on the model were generated:

- H1 (Hypothesis 1): Repeated landings outside touchdown zones without causing runway overruns reduced flight crews' perceived risks;
- H2: Flight crews' reduced perceived risks reinforced further landings outside touchdown zones increasing the actual risks;
- H3: The perceived risks increased soon after several overruns;
- H4: The ensuing inventions reduced the actual risks;
- H5: The resultant time without overruns gradually reduced the perceived risks;
- H6: The reduced perceived risks have caused an increase in the actual risks and may cause future overruns.

Figure 1: Landings inside and outside Touchdown Zone.

The data on percentage of landings outside touchdown zones show the hypotheses are partially supported in that the actual risk parts of the hypotheses are consistent with the data. Data regarding the perceived risks were not available to test the perceived risk parts of the hypotheses. Recommendations were made on actions to be taken (e.g., NoD reduction training, NoD survey, and NoD checklist) based on the partially supported hypotheses.

SYSTEMIC REDUCTION OF SAFETY RISKS FROM NOD IN CONTINUATION OF UNSTABLE APPROACHES

If unstable approaches occur, flight crews are required to follow standard operating procedures (SOPs) to execute go-arounds. However, often unstable approaches are continued (see Figure 2). Several studies have shown that only 3-4% of unstable approaches ended up with go-arounds (e.g., Rosenkrans, 2015; Smith & Curtis, 2013). In other words, the majority of them were continued, representing one of the major safety risks across the aviation industry. This has been viewed as a NoD problem (IATA, IFALPA, IFATCA, & CANSO, 2017). A Boeing team and a professor in China developed a systemic model of NoD associated with continuation of unstable approaches. The team has been collaborating with an airline in China on this topic since March 2022. The following steps have taken place:

- Approximately 320 pilots participated in a NoD survey, which was based on the specific systemic model of NoD, to reveal what factors contributed to the NoD problem and to what degree.
- 18 pilots participated in NoD interviews to lead to a deeper understanding of the factors that contributed to the NoD problem.
- The data from the NoD survey and interviews were analyzed.
- Based on the survey and interview data analyses, the Boeing team and the airline identified solutions to reduce the NoD and prioritized the solutions based on their urgency and resources available.
- Most of the agreed-upon solutions have been implemented.

Results of Quick Access Recorder (QAR) data analysis indicate that after the implementation of

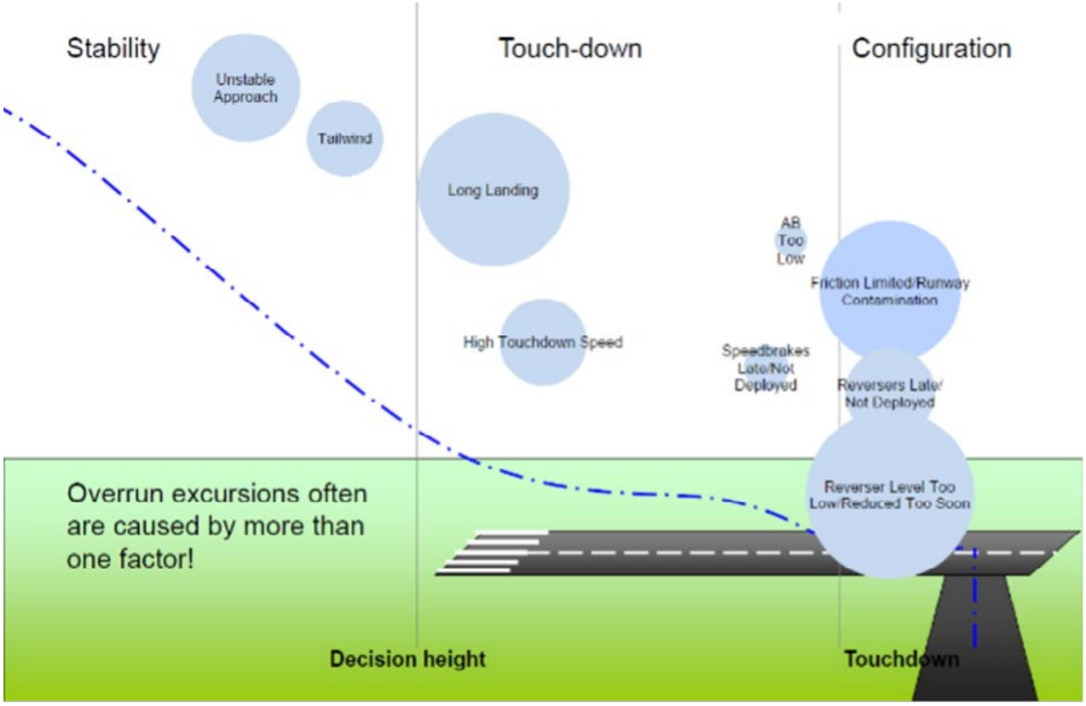

Figure 2: Approach and Landing (the Boeing Company, 2017, Slide3).

the solutions, there has been a significant increase in the percentage of the go-around after the start of unstable approaches (i.e., significant decrease in the percentage of continuation of unstable approaches). The results suggest a significant reduction in the NoD-related safety risks.

CONCLUSION

Normalization of deviation (NoD) is a common, risky, yet elusive issue in safety across multiple industries. Therefore, successful NoD reduction represents a major opportunity. A general systemic model of NoD has been developed at Boeing, which captures the complex, non-linear, and dynamic interactions among multiple factors inherent to a socio-technical system that cause NoD. The model has been extensively shared across Boeing and with three customer airlines of Boeing. Based on the general model, specific systemic models of NoD have been developed to solve specific NoD problems. Subsequently, NoD awareness training, methods, tools, processes, and solutions based on those models have been developed. They were provided and/or used to improve workplace safety at Boeing and aviation safety at one of the three airlines. All those efforts have resulted in unprecedented insights—how multiple factors inside and outside a socio-technical system interact with one another in a complex non-linear fashion leading to the NoD problems. Some of those efforts have seen significant reduction of NoD, NoD-related incidents, and NoD-related safety risks.

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COMPETING INTERESTS

No Competing Interests.

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