Employee Involvement

The Safety Assurance Network

How Toyota makes sure safety is everyone's job

By Jorge A. Colazo and Carlos Talpone

TOYOTA IS WELL KNOWN for its benchmark production system, a complex set of tools, techniques and philosophies that yield products of the highest quality and excellent value. But not many people know that Toyota's production practices are supported by a meticulous attention to continually making work safer. The company's philosophy about workplace safety can be summarized in the words of Eiji Toyoda, one of the company's founders: "Safe work is the door to all work" (Toyota Motor Corp., 2000). This means that no kind of skilled, productive and quality work can happen effectively and efficiently if its potential impact on workers' safety was not carefully studied and addressed as a prerequisite.

Similar to what the company does in terms of quality and productivity, Toyota achieves stellar ratings on industrial safety by empowering workers with tools and training that allow them to take an active role in making their workplace safer.

The Safety Assurance Network

One interesting safety initiative is known as the safety assurance network (SAN). SAN is a structured method that enables workers to identify, prioritize and act upon concrete workplace safety and health hazards. Drawing from the authors' experience in implementing SAN in a Toyota plant, this article describes the conceptual framework for this method and reviews the steps followed for its implementation.

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Toyota's work philosophy empowers workers to use and grow their skills to the fullest in designing, maintaining and improving the way in which they work. Improving workplace safety is no exception to this philosophy.

However, evaluating the safety hazards and developing countermeasures that would eliminate potential risks often pose particular challenges. This demands not only a good degree of worker involvement but also specialized technical and regulatory knowledge normally restricted to highly skilled safety engineers within a company's industrial safety and health (IS&H) department. As many practicing managers can attest, successfully creating a synergy between production and maintenance workers and IS&H staff is no easy task.

In everyday practice, the different industrial safety stakeholders (e.g., workers, IS&H, legal and insurance department, top management) frequently encounter barriers that seem to prevent line workers from being actively involved in safety initiatives (Harms-Ringdahl, 2003).

One of those barriers is a perceived divide between two different mindsets—on the one hand, the drive for efficiency and quality of production line workers and supervisors, and on the other hand, IS&H's concern with technical effectiveness and legal compliance, all of this while strictly adhering to mandated corporate policies. SAN is one of several unique tools that Toyota uses to bridge this divide and boost the level of worker involvement.

SAN is a method for identifying, classifying, prioritizing and eliminating sources of safety hazards. It is a cross-functional, team-based method that brings together line workers, production supervisors and safety engineers to meet on site regularly to assess safety hazards. It is an observational and experiential technique that identifies hazards during the controlled execution of the actual work which can be subject to those hazards.

The method is not proprietary to Toyota and variations can be found at use in other companies—particularly in Japan—and in industries other than the automotive sector (Masuda, Yokose, Tsunoda, et al., 2000; U.S. Department of Defense, 2000; Clemens & Pfitzer, 2006). But perhaps what is unique with Toyota is its particular implementation method and the emphasis in considering SAN the backbone of its safety policy.

SAN produces a concrete, actionable list of problems whose solutions are tracked and accomplished by the same team members who analyzed the hazards. As a valuable by-product, the same team polishes the skills needed to effectively deal with future safety hazards. Also, implementing SAN creates an industrial safety department that is better sensitized to worker needs and their way of appreciating safety issues.

In the SAN framework, it is understood that accidents occur when a hazard source interacts with a worker through this person's work activities, producing a hazard that can, in turn, result in a safety incident. For example, an exposed electrical wire is a source of an electrocution hazard. If the exposed wire comes into contact with the worker during the work sequence, an electrocution hazard is generated; this can result in an incident if, for example, the wire is live at the moment of contact with the worker or the worker is not wearing proper protective gear.

SAN & Major Safety Hazards

Typically, Toyota focuses a SAN implementation on the so-called *STOP6* or *big six* types of safety hazards. This classification is based on years of experience which determined that six main types of hazards are those that most impact the continuity of operations and the health and well-being of workers throughout the global network of company sites. The STOP6 hazards are (in no particular order):

- caught in machinery;
- contact with heavy objects;
- contact with moving vehicles;
- falling;
- electrocution;
- contact with heated objects.

This set of hazards can be adapted to the particulars of a plant where the SAN program is being implemented. For example, in one implementation in which the authors participated, the hazards considered included contact with chemical substances, particulate matter projection and fire hazards, as well as the STOP6 hazards.

Each company should independently determine the set of hazards it wants to address through SAN. The authors recommend gradually expanding the number of hazards from a starting group of three or four in order to make more manageable the requirements the program imposes in terms of training and workload.

The SAN Framework

The SAN provides a useful framework for identifying and later either eliminating or reducing the impact of the hazard source. Concretely, a SAN program results in the identification of hazard sources, classifying them into a grid or network based on two main dimensions: 1) the probability of the hazard occurring and 2) the seriousness of the consequences if it were to produce a safety incident. The former dimension is called *assurance level,* and the latter is called *severity.*

Hazard Assurance Level

As noted, results of a SAN assessment are displayed in the form of a matrix. One of the two dimensions of the SAN matrix is called hazard assurance level or, more concisely, assurance level. The assurance level represents the relative probability of a hazard source triggering a safety incident. The matrix has four assurance levels, named in ascending order of probability as S1, S2, S3 and S4.

Level S1 is present when the hazard is impossible because there is no potential source of that hazard. For instance, this would be the situation of analyzing contact with heated objects in a work environment where absolutely no object is or can ever be above room temperature. Level S1 does not require further action or any countermeasure, yet its existence must be objectively assessed. Often, after careful examination, some hazard source is discovered where previously the hazard had been a priori discarded.

Obviously, level S1 implies that no safety incident is possible in relation to the hazard being evaluated. Although this is a desirable condition, the SAN implementation team must be certain that no item is overlooked in order to detect every possible source of the hazard before assigning S1 (and not a riskier assurance level) to a job under evaluation.

This is accomplished in the SAN evaluation meeting by following a hazard source checklist that contains every possible known hazard source for the plant's work environment. There is one such list for every hazard type (e.g., electrocution, falling). These lists are updated and expanded constantly by IS&H staff. An abridged example is shown in Figure 1.

Level S2 occurs when hazard sources exist (at least one hazard source in the corresponding checklist was found to be present), but some barrier prevents the hazard source from interacting with the worker. One can point to three variants of what is considered a barrier between worker and hazard source.

Abstract: *This article describes the safety assurance network (SAN), a tool used to involve workers in the identification and elimination of potential safety hazards. The authors explain the conceptual framework and the steps to follow when implementing this method. SAN not only promotes improved workplace safety, it is also a powerful tool to enhance teamwork and raise workers' awareness of unsafe conditions.*

Figure 1

Hazard Source Checklist

Safety Assurance Network Hazard Source Checklist *Hazard Type: Electric shock/electrocution* **DO NOT** assign level S1 if any of the following is present	
1	Electric panels
2	Electric wiring (exposed)
3	Busbars
4	Electric tools
5	Electric lighting
6	Electric sockets or plugs
7	Electric motors
8	Capacitors
9	Batteries
10	Electrostatic buildup
11	. . .

The first is when an actual physical barrier, such as a safety fence or safety guard, makes interaction impossible. The second is an infrared barrier that is interlocked with the hazardous machine or some other kind of foolproof device such as a dead man switch. The third is when the location of the source within the workplace is such that workers cannot engage the hazard source (e.g., when considering heated objects the only hot objects are lightbulbs on a high ceiling and, thus, inaccessible to the worker).

In any case, a barrier is deemed effective only if it cannot be easily tampered with by the worker who occupies the position under evaluation. If no barrier is present or is likely to be ineffective, the hazard source must be examined within the prescriptions of the next assurance level—S3.

Figure 2

The SAN Matrix

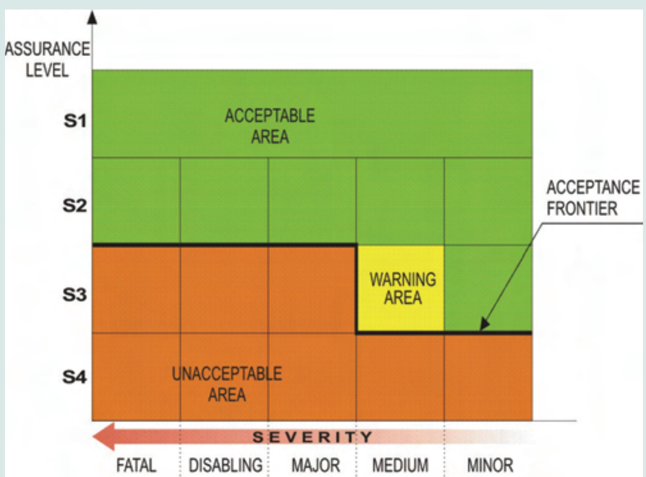


Figure 3

Work Sequence

Work Sequence Standard Sheet

Process number: 7 Process name: Rear door assembly

Operation number: 11 Operation name: Hinging and brazing

Step	Description
1	Identify model number and depress instruction button
2	Set rear door assembly in positioning fixture
3	Set upper and lower hinges on fixture
4	Depress "Hinge Clamp ON" button in control panel
5	Hold impact wrench and bolts with right hand
6	Tighten bolts
7	Pick up blowtorch, fire up and pick up brazing rod
8	Braze door frame's front side
9	Braze door frame's back side
10	Shut off blowtorch, return to stand and return brazing rod
11	Depress "Hinge Clamp OFF" button in control panel

Level S3 is present when hazard sources are present and when avoidance of the hazard rests solely on the fulfillment of procedures or work standards, such as following instructions in a manual or adhering to some standardized work sequence, or using prescribed PPE. In brief, S3 is assigned when avoiding the hazard depends primarily on the worker following some rule or directive. It is said, therefore, that level S3 is rule-based.

However, even when S3 is based on rules, these rules must have the following four characteristics:

1) The rule exists and is documented. There must be an official written record of the rule in question (not a verbal instruction only) which is subject to a procedure that requires its periodic control and update. The rule, whichever it is, must be validated with supervisory signatures and correctly dated. The documents must be easily accessible and understandable by the workers it intends to protect. A procedure must be in place to ensure that the worker knows of the rule and understands its prescriptions. These procedures are normally part of any worker's basic safety and health training before occupying his/her job position.

2) The rule is adequate. The rule meets all technical requirements—for example, it requires the correct safety gear and recommends actions that are sound from both a safety engineering and a legal standpoint.

3) The rule is actionable. Its requirements do not impose a burden on workers that will likely result in its factual dismissal—for example, when safety rules demand the use of uncomfortable equipment that results in lack of compliance by workers (given that there are alternatives) or the use of ergonomically incorrect movements or the following of ill-designed work sequences. In brief, the rule should be realistic and pragmatic enough to be easily embraced by workers.

4) The rule is actually being followed. This means that beyond all previous considerations, direct observation of the job must confirm that the rule is being used exactly as it was intended. If this is not the case, the rule is reevaluated in consultation with both IS&H staff and the workers who should be following it.

Rules that do not comply with all four factors are deemed not effective for safety purposes. Besides prompting their reevaluation and upgrade, this demotes the assurance level to the next and lowest assurance level: Level S4.

Level S4 appears when hazard sources exist and no provision is in place to avoid the interaction for that source and the worker, resulting in a potentially unsafe situation. This level is also present when a rule that should prevent the accident from happening is in place yet does not comply with the four conditions of existence, adequacy, actionability and fulfilment.

Examples are when PPE exists and is used, yet it is not adequate for the hazard (e.g., using respirator masks for particulate matter when masks for organic solvents should be used). Another example is when no written work procedure is in place to show the safety hazards of the work sequence, or when the work sequence asks the worker to perform some action that is not reasonable, or when the worker simply does not follow the rules, irrespective of everything else, which is determined by direct observation.

When a worker is observed not abiding by work rules designed to prevent accidents, s/he is immediately interviewed in order to examine the reasons for the noncompliance, but the worker will never be blamed. Toyota believes the line worker will not reasonably put him/herself in danger. When a work rule is not followed, something deeper must be occurring—something related to the management system, such as excessive line speed, not enough skill development, unskilled supervision or limited training. It is the line supervisor's responsibility to revert the situation to a fully compliant one—and not exclusively the worker's burden. Level S4 is the most undesirable of the four assurance levels.

Figure 4

SAN Evaluation Checksheet

SAN Evaluation Checksheet

Hazard type: Burns

Process Number: 7	Process Name: Rear door assembly			
Operation Number: 11	Operation Name: Hinging and brazing			
Work Sequence Evaluation	Evaluation date: 12/12/2007	Date Updated: 2/05/2008		
Step	**Description**	**Assurance**	**Severity**	**Status**
1	Identify model number and depress instruction button	S1	N/A	N/A
2	Set rear door assembly in positioning fixture	S1	N/A	N/A
3	Set upper and lower hinges on fixture	S1	N/A	N/A
4	Depress "Hinge Clamp ON" button in control panel	S1	N/A	N/A
5	Hold impact wrench and bolts with right hand	S1	N/A	N/A
6	Tighten bolts	S1	N/A	N/A
7	Pick up blowtorch, fire up and pick up brazing rod	S3	MA	⊕
8	Braze door frame's front side	S3	ME	⊕
9	Braze door frame's back side	S3	ME	⊕
10	Shut off blowtorch, return to stand and return brazing rod	S3	MA	⊕
11	Depress "Hinge Clamp OFF" button in control panel	S1	N/A	N/A

F: Fatal D: Disabling MA: Major ME: Medium MI: Minor

Hazard Severity Level

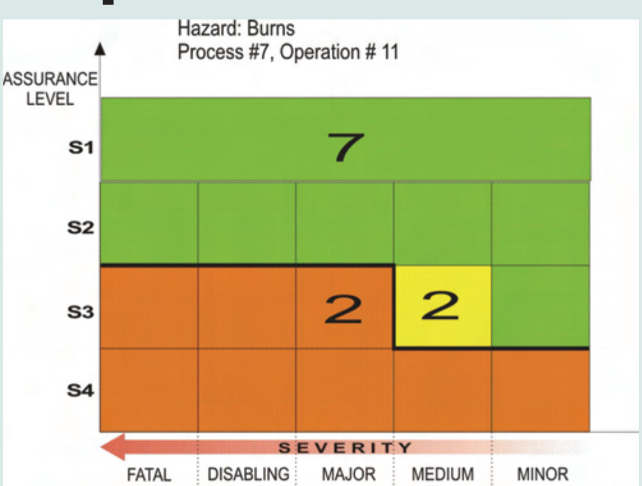
The second dimension in the SAN matrix is called severity level. The severity level classifies hazard sources by the gravity of the potential consequences of the incidents they may generate. The five severity levels are fatal, incapacitating, major, medium and minor.

- Fatal is when the incident would most likely result in the death of the compromised worker.
- An incapacitating incident is one that would likely leave the worker severely and permanently incapacitated (e.g., loss of limbs, severe organ damage or vision loss).
- A major incident is one that does not belong to either of the previous categories but would result in the loss of at least one full working day for the worker. Examples include those incidents that require hospitalization or cause lesions that cannot be treated by the company nurse or physician and require treatment in a hospital.
- Medium importance is given to those hazard sources that 90% of the time would produce a minor incident, but on less frequent occasions (e.g., no less than 10% of the time), they would result in a major accident. An example could be a cut with a sharp metal sheet, where severity is given by the location of the cut, which can vary randomly.

This classification must be meticulously scrutinized by IS&H staff. They must ensure that this classification is only given to those hazard sources that apparently are mostly inconsequential, yet when given a

Figure 5

Completed SAN Matrix



second thought can be determined to have potential to cause incidents with lost working days. In other words, medium severity should not be assigned to downgrade potentially major incidents, but rather to take into account incidents that normally would be minor but can be more serious at times.

• A minor incident has minimal consequences to a worker's health and usually the worker can return to work with minimal medical attention. Complete recovery is expected in a short time. Examples include a paper cut, or a small bruise on the knee or hands that appears after tripping on a cable.

The Safety Assurance Matrix

The combination of all possible assurance and severity levels produces the SAN matrix (Figure 2, p. 30). A SAN matrix will be created for each hazard type and each job evaluated. On the SAN matrix, company policy determines three areas: acceptable, warning and unacceptable. The unacceptable area is separated from the rest of the matrix by a line called the acceptance frontier. The location of the acceptance frontier is decided at a high managerial level in the plant's organization.

Using the SAN matrix, after the corresponding evaluation, figures representing the number of hazard sources identified at the worksite are placed in each corresponding cell. The complete matrix will then provide a graphic depiction of the safety status of the work position for the corresponding hazard type.

Additionally, the matrix provides a prioritization aid for solving the identified safety issues. Hazard sources in the unacceptable area must be remedied urgently, followed in priority by those in the warning area. The ideal situation would be to have all identified hazard sources in the green (acceptable) area of the matrix. Hazard sources should be eliminated or alleviated starting with those in the lower left-hand corner of the matrix and moving up to the upper, right-hand corner in order of priority.

The matrix structure also provides indications on how to solve unacceptable conditions: if they cannot be eliminated, hazard sources must be moved to the acceptable area by adopting countermeasures. The two ways to move hazard sources into the acceptable area are to either 1) reduce the severity level or 2) increase the assurance level for the hazard source in question.

For example, if a hot surface were discovered that would result in a major accident and whose avoidance relies on following a work procedure (the S3-Major cell of the matrix), one could attempt to increase the assurance level by surrounding the hot surface with a physical barrier, then elevating the assurance level from S3 to S2 and moving the hazard source into the acceptable area of the matrix. Alternatively, one could study whether the temperature of the hot surface could be reduced in order to decrease the severity level of the potential incident to medium or even minor.

Frequently, some combination of both approaches is attempted. The eventual goal is to eliminate as many hazard

Figure 6

Countermeasure Report

S.A.N. Countermeasure Report

Date: Shift:

Hazard: Contact with moving vehicles

Sector	Place	Sect. Foreman	Shift Foreman	Group Leader (Working Team)	Team Leader (Working Team)	Team Members (Working Team)
Initial SAN matrix		**Fatal**	**Disabling**	**Major**	**Medium**	**Minor**
Not possible	S1			3		
Barrier	S2				4	1
Rule	S3					
No Countermeasure	S4	1				

BEFORE

Man-Moving vehicle contact possible

AFTER

Physical barrier installed to prevent contact between worker and forklift

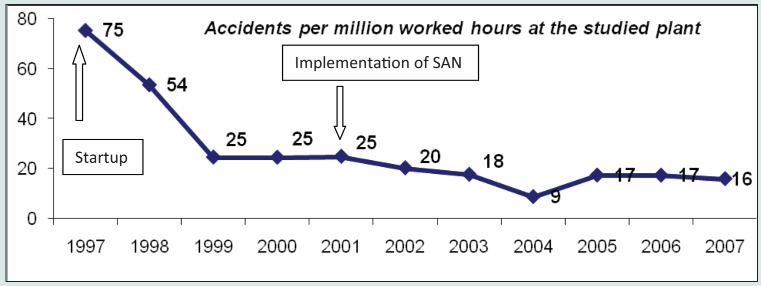
Countermeasure Impact		Ergonomics	Quality	Cost	Result	
		No Impact	No Impact	$400	Approved	
Resulting SAN Matrix		**Disabling**	**Major**	**Medium**	**Minor**	**Menor**
Not possible	S1			3		
Barrier	S2	1			4	1
Rule	S3					
No Countermeasure	S4					

Observations

sources as possible through planned countermeasures, and to move the remaining ones to the acceptable part of the matrix.

Figure 7

Statistics



Building the SAN Matrix: The Evaluation Meeting

The SAN matrix is built during the SAN evaluation meeting by the SAN evaluation team. At a minimum, this time includes a SAN implementation leader (normally a supervisory-level production employee who has received SAN training), a member of IS&H staff, a safety engineer and the team leader of the work area corresponding to the job being analyzed. Since most jobs involve the use of machines, a maintenance worker or supervisor is also part of the team. Normally, other staff members who have in the past been involved with the job under analysis are involved as well.

SAN implementation leaders are at the supervisory level and should have performed a minimum number of evaluations. They have been trained by a SAN master trainer, who typically has received guidance in a Japanese plant. The rest of the members are production and maintenance workers and first-level supervisors who express an interest in industrial safety and volunteer for the evaluation teams. All meetings and activities are performed during paid working time or those involved receive overtime pay. Usually, the basic SAN training includes one or two theoretical sessions explaining the system; after that, training is strictly on-the-job (i.e., performing actual evaluations).

At this point, it should be noted that SAN strictly evaluates neither the worker nor the work individually, but rather their interaction. The evaluation is performed by observing the actual work in the running line.

Each meeting will normally involve the evaluation of only one hazard type. To start the meeting, the SAN leader confirms the attendance of all team members (a minimum number must be present to start the meeting). After announcing the purpose of the meeting, including the workstation and type of hazard to be evaluated, the leader allows some time for small talk in order to break the ice and put everyone in a positive mood for teamwork. After this, the actual evaluation takes place.

Most jobs in an assembly line situation typical of a car maker involve performing a sequence of tasks that is repeated as many times as units are produced. This is called work sequence and is documented for each existing job in the line. An example is shown in Figure 3 (p. 30).

To evaluate sequenced work, each task in the standard worksheet is copied to a line in the SAN checksheet (Figure 4, p. 31). The team member with the most experience in the job under analysis demonstrates the job line by line, and the whole team analyzes whether hazard sources are present for that fraction of the job sequence and the hazard type being considered.

Every time a hazard source is discovered, it is assigned a severity and assurance level, often in consultation with the safety engineer, and recorded in the SAN checksheet. This process is repeated for all individual components of the work sequence.

Before closing the meeting, counts for all identified hazard sources are placed in the SAN matrix (Figure 5, p. 31), and a copy of the completed matrix and checksheets are posted in the workplace for everyone to see.

Countermeasure Follow-Up

The creation of the SAN matrix is not a goal in itself, but rather the starting point for workplace improvements, called *kaizen* at Toyota, meaning *continuous improvement.* These improvements or countermeasures are defined by production supervisors and workers, in consultation with the safety engineer who participated in the evaluation and often with the advice of external technical specialists as deemed necessary.

Progress in countermeasure implementation is updated on the SAN checksheet and matrix posted in the workplace. Progress can be observed by checking the status of a "status circle" divided in quarters by the side of each hazard source found (Figure 4, p. 31). An empty circle means no countermeasure is yet being considered. A quarter-filled circle means that an idea for a countermeasure exists, but its implementation has not begun in practical terms. A half-filled circle indicates a countermeasure is being worked on but has not yet been implemented in the workstation (e.g., a purchase order for an infrared barrier has been issued but no parts have arrived from the vendor). A three-quarters filled circle means the countermeasure is being actively implemented in the line, and evidence of its implementation is available or visible. A fully filled circle indicates that the countermeasure has been implemented.

Final approval of a countermeasure's adequacy and effectiveness is given by IS&H staff, who are responsible for confirming that any countermeasures meet legal and insurance requirements at all

The truly interesting outcome of a successful SAN program lies in the creation of a healthy, dynamic community that includes all in the plant working toward the constant improvement of the operation's safety level.

levels and for suggesting modifications if they do not. In practical terms, modification ideas are bounced between IS&H staff and the production and maintenance members of the team, who periodically meet to follow up on the pending issues.

As noted, the result of SAN evaluations can be observed by anyone walking the shop floor. Any given work position should eventually have posted SAN matrixes and checksheets for all hazard types. Countermeasure reports are also posted in the workplace (Figure 6, p. 32); these always include illustrations or pictures of the before/after situations.

The posted checksheets and the numbers on the matrices should be periodically updated (typically once a month) with any progress made in countermeasure implementation. Also, if the work performed changes in any way, the position should be scheduled for reevaluation as soon as practically possible. Only those parts of the operation that changed are reevaluated.

In one implementation the authors led, the site reported a 25% decrease in accident frequency index (accidents per 1 million work hours) after 2 years of implementing SAN (Figure 7, p. 33). Although it is impossible from the data collected to distinguish the effect of the SAN implementation from other safety-related initiatives in effect during the same time period or from a natural learning curve effect, the hard data and anecdotal reports from line workers and IS&H staff support the positive influence of the program on the plant's safety level.

Extensions of SAN

The basic SAN evaluation can be extended to cover other types of events. For example, a worker will not only perform sequenced, repetitive work, s/he may also perform nonrepetitive tasks such as those related to total productive maintenance, cleaning tasks in the workstation, arrangement of tools and other cross-checks of equipment or workspace. These tasks are of no less importance from the safety hazard point of view and, as such, they could be included in a SAN evaluation. Note that off-sequence tasks can have different frequencies (e.g., daily, weekly, monthly, yearly); all of these tasks may be included in the SAN evaluation.

Also, a worker is subjected to risks, even if s/he is not working, by merely being present in a working facility that is inherently risky. For example, traveling to and from from the plant's cafeteria can involve serious risks such as being hit by a forklift or catching a flying spark from a spot welding machine. Those work environment hazards can also be evaluated using SAN.

Ergonomics can also being evaluated using SAN. Part of the attraction of implementing a SAN program is that the method is flexible enough to be adapted to myriad different needs of very diverse industries and work technologies.

Finally, companies seeking to certify their safety management systems can use SAN as their principal method for hazard assessment and evaluation.

Conclusion

The implementation of a SAN program in a large industrial facility can take several years. Given the inevitable changes to work conditions, production levels and technology, the evaluation never ends and never seems to be completed. However, this should be of no great concern. Although it would be ideal, the goal is not necessarily to complete a SAN evaluation for every possible job and hazard, and have all necessary countermeasures implemented.

The most obvious outcome of a SAN program is the elimination or reduction of hazardous conditions throughout the plant. But perhaps the truly interesting outcome of a successful SAN program lies in the creation of a healthy, dynamic community that includes all concerned actors in the plant working toward the constant improvement of the operation's safety level.

In the authors' experience, implementation of a SAN program boosts the level of worker participation in problem solving, not only for safety. It is also a vehicle to increase safety training, raise morale, break down barriers between production, maintenance and IS&H staffs, and increase workers' awareness of unsafe situations, while decreasing worker apathy toward reporting unsafe conditions.

SAN is a tool that Toyota uses to improve safety, foster teamwork and heighten mutual understanding among all the industrial safety stakeholders. Its theoretical foundation is purposely simple, relying on easily understandable concepts, and its results are powerful. It provides a flexible vehicle for safety improvement all the way from hazard identification to countermeasure implementation, and provides several intangible benefits such as increasing teamwork and breaking down mental barriers between the production and safety functions in the company. Overall, it helps create a win-win scenario where safety is everyone's job. ■

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