Implementation of risk management in manufacturing industry- An empirical investigation

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Abstract— Every manufacturing organization faces undesirable and unwanted setback in its day to day operations. These are referred to as operational disturbances in this research. The disturbances put an organization at production, economic and occupational risks. To deal with these risks, an organization needs to implement an appropriate risk management process, which is what this paper aims for. In this connection, we have developed a conceptual model that describes the generic approach of risk assessment and outlines the gaps in the assessment steps that may hinder the successful implementation of risk management. An empirical investigation with multiple case studies in New Zealand has been performed to verify the model. Finally, a comprehensive framework is developed for successful implementation of risk management in manufacturing organizations.

Keywords—operational disturbance; risk management; implementation; manufacturing

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I. INTRODUCTION AND BACKGROUND

Over the last two decades, manufacturing industry in general tended to focus heavily on advanced management and production activities to increase organizational flexibility, enhance product quality and to increase innovative capability. In contrast, the majority of the manufacturing sectors (except the chemical and food sectors) in manufacturing put less focus on the management of risks [1]. Although manufacturing industry incorporates project management techniques within its operations (for product development and for investment), risk management is still considered an anomaly. In the context of risk management, companies focus mainly on government-led and/or organization-led regulations for health and safety. The downside of depending only on compliance verification methods for safety is that an organization is not actively designing optimal safety into its systems. Compliance with the standards and regulations generally requires the least effort and is not always sufficient to prevent accidents. Safety systems in a manufacturing plant need to be optimized by changing the thinking of the manager/engineer to constantly strive to make the total system safer and not just to blindly follow the regulations [2]. Precautionary practices such as OSH (occupational safety and health) and other safety-related programs should, if properly implemented and practiced, ensure a better health and working environment inside the organization. They do not, however, ensure the smooth running of the organization or minimize its risks operationally, technically and/or financially.
people, or from external factors. Occupational risk is considered to be the risk associated with health and safety of employees. Finally, economic risk is considered to be the risk associated with commercial and business performance. To handle these three types of risk successfully, an organization needs to continually scrutinize the performance of its strategic, operational and technical functions. In terms of strategic decision-making, the risks can be categorized into three groups: a) probabilistic risks, b) unpredictable risks and c) uncertain risks. The first type of risk is predictable and organizations know they face it. This is probably the most straightforward type of risk to manage using a formal statistical approach. In the context of probabilistic risk, both likelihoods and outcomes of unwanted events are well understood and defined [10]. It is in essence more difficult to manage the second type of risk. An organization knows that it may encounter these risks. But the causes of these risks are essentially idiosyncratic in nature, and cannot be predicted by a formal statistical approach [10]. Many operational risks fall into this category. To handle these risks, an organization would require major organizational and cultural change, which requires awareness of the risks by everyone in the organization and top-level commitment by its managers. The third type of risk is unknown to the organizations. Increasing uncertainty and unpredictability of the business environment (both internal and external) mainly results in that type of risk. In spite of the best systems and procedures that can be devised, failures and mistakes are bound to occur which would produce this type of risk in practice [10]. Constant monitoring of system performance may provide substantial information to the organization to develop strategic plans to deal with this type of risk. Managerial perspectives on risk and risk-taking significantly influence the estimation of probabilities of possible negative outcomes on a system and the focus on critical performance targets [12, 13, 14 and 15]. In the context of organizational characteristics, there are four organizational sources that influence risk behavior. These are: i) group decision-making practice (group decision-making context) [16]; ii) organizational risk culture values [17]; iii) leadership (leader’s influence) [14] and iv) organizational control system [15]. There are strong indications that individuals “do not trust, do not understand or simply do not use precise probability estimates”, and they therefore come up with erroneous estimations about the potential consequences that lead them into ineffective decisions [15]. It appears that the modern term ‘risk management’ was first used in the early 1950s, which was reflected in one of the earliest publications dealing with risk management, namely, The Harvard Business Review in 1956 [18]. Numerous definitions of risk management have since abounded in the risk literature. Risk management is intended to control the level of risk and to mitigate their effects, and as such has become a major part of an organization’s activities with its main aim being to help all other management activities to reach the organization’s goals directly and efficiently [4, 5, 8, 19, 20, 21 and 22]. Risk management must involve procedures, resources, timetables and other factors so as to be able to fulfill safety and other programs, leading to a reduction of the risk level. The commonalities among the definitions yield a set of critical features regardless of the particular industry being considered. These commonalities include [9]:

(i) risk management is a concept defined at the corporate level that refers to the shared contributions among all managers of an organization, (ii) risk management is concerned with risk factors and closely related to, but not restricted to, the management and supervisory systems, (iii) risk management demands appropriate planning, proper execution and a continual monitoring system and (iv) risk management needs proactive as well as quick reactive responses from the decision makers. It is noted that all definitions imply that risk management starts with the identification of risk in an organization. However, the risk itself, in fact, becomes a complex and topical process that is often ill-defined within organizations and the responsibility of management is often diffused and ambiguous [23]. This means that the success of a risk management system depends significantly on the meaningful identification of risk, which is not possible by senior managers’ (or risk managers’) experience and knowledge alone. For this, the active and voluntary participation of all members of an organization is required. The positive involvement of employees in the risk management process can ensure successful strategic implementation. The employees of an organization are important in ways beyond their usefulness in identifying personnel and work environment related risks. They are the source of risk identification, and are of themselves sources of risk and potential losses [24]. Status and role conflicts among the employees and managers can hinder the success of a risk management approach. For example, wearing safety gear (e.g. safety helmets) may be neglected or ignored by an individual because of his/her political or philosophical affiliation. If an organization fails to develop a healthy safety culture which breaks down the barriers of status and role conflicts, it will not be able to develop a good safety management system. In that context, norms and value systems of the individuals need to be considered in developing any risk management strategy. At the implementation phase of an approach, formal feedback loops need to be established. It is found that the quantity of information available to managers to make risk management decisions is usually poor and of mediocre quality [23]. Kolman [25] states that “risk management is simply good common sense in coping with possible and actual daily mishaps, and occasional major disasters, which lead to financial losses and unfulfilled plans for individuals and organizations - indeed for our society as a whole.”

In conceptualizing different risk management approaches and their associated limitations, we have identified some important factors that need to be given special emphasis while developing a generic risk management framework. These include: (i) participation and contribution of everyone in the approach to risk management needs to be confirmed; this may require cultural change to some degree, (ii) the continual assessment of performance of management, employees and the system itself, needs to be integrated with business strategies, (iii) formal causal feedback loops between the interested parties need to be established, (iv) risk assessment tools and techniques need to be purposeful and specific, (v) changes in the work environment (internal and external) continually need to be monitored and adjusted within the risk management strategy, (vi) formal training and development programs for managers and key employees need to be incorporated. People conduct their daily activities and pursue their business objectives; therefore, managers need to set a tone about risk-
consciousness. Sitkin and Pablo [12] note, “Organizational members come to view their world through the lens of their organization’s culture, which can distort their perceptions of situational risks, sometimes by overemphasizing risks or underemphasizing risks” (p.21). According to them, top management plays a particularly important role in influencing perceptions that risk is or is not legitimate. Subtle cues from leaders about their preferences regarding risk can powerfully affect the risk perceptions of other decision makers. Thus, to have knowledge of the perceptions of top managers’ risk behavior means to have insight into acceptable risk behavior of an organization. We, therefore, conceptualize an organization’s perception of risk behavior collectively as its ‘risk culture’. Risk culture thus encompasses an organization’s appetite and tolerance for risk in its daily operating activities and decision-making processes.

According to contemporary risk management frameworks, risk management possesses some distinct features compared to the traditional risk management process. The features include: the risk management methodology is considered as a cyclic process (as opposed to sequential one-off activity) with the aim of continuous improvement; the objectives of risk management are suggested to be incorporated with other business strategies and goals; and that the heart of every step of the risk management process is considered to be an effective information and feedback mechanism [22, 26, 27, and 28]. In contrast with the traditional narrow technical-economical risk management approach, the contemporary frameworks view risk management as a holistic or enterprise-wide management approach that combines cross-functional activities to achieve business objectives by identifying, evaluating and managing operational risks. These explicitly focus on the necessity of the information and communication system. They, however, do not emphasize the necessity of identifying the possible loopholes in information and feedback loops. They are not specific about the necessity for the development of effective causal feedback mechanisms. In connection with this, we consider that inadequate and inappropriate risk information may negatively affect even a good policy from strategic decisions and resource allocation, and may badly affect a mediocre policy. Thus, to know how and why some gaps may exist in the risk assessment process becomes the major research agenda of this paper.

According to Close [24], following a systems approach, a risk manager must focus upon: i) changes in the internal structure, ii) changes in personnel and, iii) changes in interpersonal relationships. Thus, methods of risk identification need to be dynamic in their operation. Risks emanating from day-to-day operational processes need to be identified. As a whole, an organization needs to develop an effective risk culture along with a specific risk management program. Otherwise, the success of any risk management framework would be incomplete. It is found that numerous research studies have been carried out on risk and risk management. Most of them, however, have focused on particular industries such as nuclear plants, aviation, space exploration, chemical process plants and other areas where the consequence of system breakdown is considered severe or catastrophic for human beings or the environment and/or where the potential financial loss is significant [21, 32, 33, 34, 35, and 36]. Research on risk and risk management in other areas including medical science, transportation, and construction engineering has also significantly expanded with time [37, 38 and 39]. Risk management research on project management (particularly in product or process design) of large manufacturing industries has also been practiced [40]. In contrast, lower priority has been noticed in the management of risk in the other manufacturing sectors where the risks are considered to be less than catastrophic and most studies have concentrated solely on the risks associated with safety and occupational health and hazards [41]. These sectors are found to be less focused in their practice for risk management as a part of a self-regulatory system. Both the scarcity in academic research literature and practitioner concern supports this claim [9]. Most of these sectors however, manage occupational safety and health related risks. For example, ergonomic risk assessment has become a growing concern in the Wood and Furniture manufacturing sector [30]. In fact, irrespective of the industrial sector, occupational safety and health (OSH) draws special attention to both government regulatory bodies and employers. The utilization of standard risk assessment methodology in manufacturing industry in general, is usually limited to food and chemical process sectors. Government regulations, public demand and self-regulatory requirements associated with these industries, basically encourage and in some cases oblige them to implement certain risk management methodologies. For example, to standardize food safety activities, the Australian and New Zealand Food Authority endorsed the principles of HACCP as described in the 1996 CAC (Codex Alimentarius Commission) guidelines for HACCP development [29]. The governments of these countries have direct and indirect influence over the food industries to follow HACCP methodology. However, available risk assessment techniques focus on the main hazard sources and help to divide a complex system into smaller and more manageable nodes for study. While any of the techniques can produce a thorough list of important system failures, causes, consequences and controls, none lend themselves to rigorous risk acceptability analysis. Furthermore, none of the techniques are necessarily effective in prioritizing the risks associated with identified failures, nor provide a process to assess the relative effectiveness of proposed corrective actions [31]. Despite having some limitations, these methods are successfully implemented in reliability and failure analysis of a system, particularly in process industries. Also, these are proven to be very useful tools to deal with the residual risks of a physical system. Although much research has demonstrated the theory of risk management and its positive effects on business performance, there is still a lack of empirical evidence as to how the theory will be applied effectively in manufacturing organizations in the studied sectors, and how the effects occur in practice. We attempt to fill this gap and provide empirical evidence of the means by which conceptual limitations in risk management leads to the ineffective application of traditional risk management methodologies. The fact is that, significant hazards and operational disturbances are present in every manufacturing organization and an integrated approach which considers operations, employees, assets and the management approach, is necessary to discover the risks and to develop methodologies for managing them. In this research, a conceptual model is developed to demonstrate
the risk assessment process and underlying gaps in the process. Finally, a comprehensive framework for risk management approach for effectively dealing with operational risks. This paper discusses the model and the developed framework.

II. RESEARCH METHODOLOGY

The research methodology adopted here include: i) a literature survey to identify the key perception of risk and risk management; ii) developing corresponding conceptual risk assessment model to demonstrate major gaps; iii) multiple case studies to discuss the model and iv) developing a comprehensive framework for risk management based on the theoretical analysis, model and the experience gathered from case studies. The conceptual model is developed based on the literature review and authors’ own experience over 16 years working in manufacturing environment. The follow-up case study approach is chosen as “---- an empirical inquiry that investigates a contemporary phenomenon within some real-life context and a methodology involving multiple sources of data which provides the fullest understanding of the phenomenon and improves the validity of research implications through triangulation” [42]. Case studies, in fact, are an ideal methodology when a holistic, in-depth investigation is needed [43]. Eisenhardt [44] stated that “The case study is a research strategy which focuses on understanding the dynamics present within a single setting” (p.534). Concerning the proposed model, we realized that case studies would be more suitable to verify and validate them as these studies could provide dynamic and multi-sourced data. To gather pertinent data to elaborate and refine the proposed model, a theoretical sampling was chosen [45, 46, and 47]. In the case studies, the sources of data were structured interviews with the managers, verification of documentation, archival records and direct observation, most of which were recommended by Yin [42] and Charmaz [45]. Multiple sources of data were utilized to establish the reliability of the study. In the structured interviews, two questionnaires were used. The first questionnaires were concerned with the perception of operational risks and key aspects related to risk management (methods, and tools and techniques). The second questionnaire was concerned with the status of risk management. The questionnaires proved to be unpopular and the majority of managers were reluctant to complete them. Supplementary data were collected through semi-structured and informal interviews with managers and other key employees, and reviewing relevant documents.

III. A CONCEPTUAL MODEL FOR RISK ASSESSMENT

There are two categories of risk in a system, residual risk and entropic risk [48]. Residual risks are those that are inherent in a system, whereas entropic risks are those which are caused by the degradation of system factors. To deal with the residual risks of some manufacturing systems, which are potentially harmful to the environment on its failure (such as nuclear power plants, chemical process industries or oil storage facility), scientific studies based on probabilistic statistical measures have been developed, refined and practiced over the years. These measures generally provide a comprehensive safeguard to an organization while the system performs under normal operating conditions. The fact is, however, that a system is usually comprised of different subsystems and the degradation of any subsystem can lead the whole system to fail. Not only that, human error is common in practice, and plays a significant role in degrading a subsystem or the system itself. Therefore, it is hard, if not impractical, to ensure that a system will always operate under normal conditions. For example, in 1984 the Bhopal crisis (at Union Carbide (I) Ltd) in India originated from a faulty pipe-washing operation, which was a consequence of an erroneous operational technique [49]. The crisis was also linked to inadequate maintenance, safety practice and training. The underlying issue was, however, that the system was not in fact operating under normal conditions even though it was supposed to be. As a result, the residual risk assessment of the plant in the first place did not provide a real safeguard. The learning point from the incident is that residual risk management alone cannot be effective for controlling risks of a complex industrial plant; it needs to be incorporated with entropic risk management. An organization needs to engage its efforts constantly in monitoring its system’s performance to reduce entropic risks. In that context, a conceptual model for risk assessment is developed (Figure 1). The methodology in the proposed model is considered as cyclic process (as opposed to sequential on-off activity) with the aim of continuous improvement and the heart of each step of the assessment process is considered to be an effective information and feedback mechanism. The model also incorporates the possible gaps between the steps and the motivational or driving factors behind the success of each step.

According to it, five strategies should be developed stepwise. It is considered that the success of higher order step depends on the effectiveness of the lower order step. The success in each step itself depends on complete knowledge on specific driving factors mentioned in Figure1. Beginning with the development of clear perception of risks as one of the key steps indicates that there is a need for strategy formulation to deal with perceived risks. In order to recognize and resolution of risks, there is a need of successfully implementing

![Figure 1: Model of risk assessment for operational disturbances](image-url)
formulated strategies. Finally, a structured analysis is must to assess the significance of the risks. Periodically, these steps should be refined and followed as part of continuous improvement. Concerning the perception of risks associated with operational disturbances, this research deals with some specific organizational activities; how an organization becomes aware of disturbances; how it interprets consequential stimuli (how they classify, simplify, and distinguish between disturbances), how the organization encodes and categorizes disturbance-related information and finally how it retrieves encoded information to make judgments and decisions about the disturbances. It is likely that managers formulate their strategy to deal with risks according to their own perception about the risks. If the perception is somewhat wrong, the strategy will be inappropriate. That means there will be a gap (Gap1) between Step 1 and Step2. In strategy formulation for managing perceived risks, management usually establishes the priorities for dealing with risk factors. If the prioritization misses fact-based information, scientific judgments or estimations of actual or potential risks cannot effectively be made. That means the implementation of risk assessment will be erroneous. Thus, a gap (Gap 2) will exist in between strategy formulation and strategy implementation. The successful utilization of available resources to control or manage risks depends on human assets. Both the managers and employees need to have adequate awareness and commitment to the intended tasks. This relies significantly on the “sense of coherence” of the people involved in the system, which is composed of three elements, namely comprehensibility (explicable and consistent stimuli developed by the internal and external environment), manageability (resources are perceived to be available on demand) and meaningfulness (demands or challenges worthy of participation and individual investment) [50]. This means that an organization needs to provide enough motivation, required resources and rewards to its employees for successful implementation of a strategy. The fact is that there might be a gap between the perceived motivation and the actual motivation of employees. Likewise, there would be another gap between the perceived performance and the actual performance of employees, which results in a failure of the strategy at its implementation stage. Without eliminating these gaps, if an organization tries to control and manage perceived risks, it cannot be successful because of erroneous practices in the recognition and resolution phase. Thus, there might be a gap (Gap 3) in the process. Management needs to be willing to fund the necessary elements of a risk management system, including personnel and information technology costs, and recognize that risk management is a dynamic function that must be modified and improved as the business changes. Finally, management needs to implement available improved tools and techniques to resolve any identified risk determinants, acknowledging that poor systems of internal control result in substantial losses. If the recognition and resolution of risk determinants are inappropriate, the assessment of potential risks will be erroneous. Thus, there might be a gap (Gap 4) between Step 4 and 5. Assessment of potential risks resulting from an event requires knowledge of the probability of occurrence of the event and its consequential effects. Although qualitative judgments can be used in risk assessment, in general, sound scientific knowledge of applied statistics and basic mathematics are required to assess risks effectively. Moreover, to apply the scientific knowledge in practice, detailed data for each disturbance are required. If the managers are not expertise enough about the risk assessment tools and techniques, they would come to the conclusion with misleading results. This means that without scientific judgment, management could not be able to realize the actual risks. As consequence, their perception of risks associated with operational disturbances will not be conclusive. Thus, there is a possibility of the existence of a gap (Gap 5) between the assessment phase and perception phase in the context of operational risks. According to the model, that there might be five possible gaps in the proposed risk assessment process that can hinder the success of managing operational risks. The model has been studied with multiple case studies in five manufacturing organizations located in Auckland, New Zealand.

IV. EXPERIENCE FROM CASE STUDIES

In this section, key findings of case studies are presented. First, the current risk management practices in the studied organizations are discussed. Second, the results associated to the proposed model are presented. We carried out five in-depth longitudinal case studies over twelve months, which added a holistic and richer contextual understanding about the risk management practice in the organizations. A brief description of five case companies is presented here. Because of the confidentiality agreement, the original names of the organizations are not revealed here; they are identified as A, B, C, D and E case organizations.

**Case organization A:** This organization is a manufacturer of steel-based fabricated products. It is located in Auckland. It produces structural products for household and commercial purposes. Its main products are roll-formed building products including MSS purlins and girt. It also produces some roofing products. It employs 25 full-time employees on its site.

**Case organization B:** This organization is one of the New Zealand’s leading manufacturers and installers of quality roll-formed roofing products. It has a wide range of quality roll-formed and folded color-steel and zinc-aluminum products with profiles for roofing and cladding to suit all applications. Its Roofing and Cladding operation has manufacturing branches based in different locations. Its Auckland site employs over 75 employees and operates in two shifts from Monday to Friday. It is located in East Tamaki, Auckland. It supplies its products to local markets all over New Zealand.

**Case organization C:** This organization is a leading New Zealand manufacturer of reinforcing mesh and nails and a supplier of reinforcing rods, steel plates, and structural steel as well as a wide range of other steel and wire products for the engineering and construction industry. It is located in East Tamaki, Auckland. It manufactures reinforcing mesh of all standard sizes for tilt slabs, concrete tanks, commercial flooring components and security purposes. It manufactures different types of nails (bright, galvanized, stainless steels and silicon bronze). It also supplies tie wire coils and all tie wire products to the building, contracting and engineering Industries. It consists of 10 workstations, employs 50 full-time employees and operates in two shifts per day from Monday to Friday.

**Case organization D:** This organization manufactures a wide variety of wood products including pre-nail framing and trusses for house building. It employs 25 full-time employees and operates in one shift per day from Monday to Friday. It consists of several power saws, wood lathes, drills, router machines, groove cutters, power staplers, coating machines and some testing facilities in four major workstations. Power cutting, manual cutting, power stapling, nailing, gumming, coating, aligning and assembling are the
The executive, Mr. Steve, from Case A responded: “We identify all the hazardous areas on the production floor. We provide safety gear to our machine operations. We perform two safety drills annually to keep our employees alert about fire hazards. We have a safety committee composed of five people, including two representatives from the shop floor employees, which conducts a safety meeting monthly. We have a health and safety manual, one copy of which is given to every employee. We have specific forms for recording and reporting accident-related information, which are provided to the relevant personnel. There are some other associated documents including the OSH Form (serious harm), the IF (Improvement Form) and the Accident Investigation Report, which are used to meet our obligations under the Health and Safety in Employment Act and Regulations”.

The executive, Mr. Gareth, from Case B responded: “We collect all the accident and incident reports monthly and discuss these in the safety meeting. We distribute the responsibility to some of our employees. A team leader from the shop floor employees reports all the safety-related information and we discuss all the past incidents to improve the safety and reduce the risks. We have occupational health and safety manuals and incident reporting forms that comply with the requirements set by the Occupational Safety and Health (OSH) service authority of the Department of Labour. We have first-aid facilities on the factory floor”.

The executive, Mr. Stephenson, from Case C responded: “To be honest, we don’t have any formal method to assess the operational risks. We are however, very cautious about the risks for our employees in this business over the years and we have yet to face any so-called risks other than some ups and downs in our profit margin. To me, experience is the best key to manage business risks. Anyway, as I mentioned earlier, we have incident reporting forms by which we record all accidents and near-miss cases. We analyze these reports from time to time and reduce health and safety risks”.

The executive, Mr. Jacob, from Case D responded: “Sorry to inform you that we don’t have any formal methodology to managing operational risks. But, we do manage some risks based on our experience. We are concerned with fire hazards, theft cases and accidents. We have prescribed forms to report accidents and other major incidents. Our production manager looks after the risks associated with health and safety.”

The executive, Mr. Anand, from Case E responded: “I personally am very much concerned about crisis management. As a newly appointed top executive of the organization, I am trying to apply my knowledge and experience of crisis management rather than so-called risk management. I know losing a customer is a huge risk for our company. At times, it becomes very hard to satisfy the customer if everybody in the organization doesn’t cooperate sincerely. Well, we have some tools for risk management. We have accident reporting forms and safety manuals. We insure some of our key machines. We also have an insurance policy for accidental business interruptions”.

From the findings of the case study, a summary has been drawn up of the perception of managers about operational risks and their overall knowledge on practiced tools and techniques for managing such risks, which is presented in Table1. It can be concluded that the executives’ perception of operational risk is not very clear, and their perceptions of risks in general is pretty much limited to occupational health and safety. With the verification of the contents of accident/incident reporting forms and safety manuals in the organizations, it is found that all organizations use a similar prescribed form supplied by the OSH in New Zealand, which is given the caption ‘Notice or Record of Accident/Serious Harm’. The form contains the employer’s information, location of place of work, personal data of the injured person, job title of the injured person, treatment of injury, time and date of accident or serious harm, mechanism causing the accident or harm, agency causing the accident/harm (machinery, material etc.), body part affected, nature of injury main manufacturing activities in this organization. Manufacturing operations involve heavy manual labor.

Case organization E: This organization is a manufacturer of reinforcing steel and mesh for large buildings. It specializes in the fabrication and installation of a wide variety of reinforcing steel and meshes. It is one of the leading suppliers / fabricators of reinforcing steel. Customized cut and bend are the main manufacturing activities in this organization. A number of mechanized and manually operated machines are used to perform these jobs. This organization employs over 30 full-time employees.

Current practice of risk management

It is found that recognition of risk associated to operational disturbances is substantially weak in the studied organizations. The organizations do not have adequate information to identify actual losses resulting from the operational disturbances. Moreover, they do not adopt formal risk management process in their business practice. Their decisions are biased significantly by the immediate business needs. For example, management may not hesitate to change the planned production schedule to satisfy its preferred customers even though it may dissatisfy other customers and the employees or it may result in significant downtime and have other consequential effects due to the rescheduling. The cooperative efforts of employees and management, to identify and resolve disturbances by building bridges through communication, were found to be missing. Finally, the stratification of disturbances and the analysis of the actual consequences resulting from disturbances were absent. As a result, the managers of studied organizations do not possess true understanding about the operational risks. The majority of the managers of the studied organizations only focus on accidents and injuries when they consider risks in general. The statutory regulations (employment acts in particular) are basically playing a major role in motivating and often obliging them to take comprehensive measures to reduce or control accidents. Their primary business strategy is to acquire capital machinery and produce quality products. However, they consciously or unconsciously put less effort into developing human assets and to improve processes. As a result, they cannot reach their targets on quality and productivity. It is found that the organizations have a reactive approach to resolve an operational disturbance. Once a disturbance happens, the management of an organization tries to solve it as soon as possible, although the reaction time varies from organization to organization. After solving the problem, the organization usually forgets it. This has been reflected by the record-keeping of disturbances. None of the case organizations records disturbance-related information except that relating to major accidents and/or injuries. In most cases, the managers’ concept of risk is found to be limited to occupational health and safety. No categorical risk assessment is applied. The case studies confirmed that three organizations applied some of the principles of HAZOP and HACCP to formulate their own standards of practice, although the scope was limited to only occupational safety aspects. The authors further investigated with the top executives of the case organizations regarding the matters relating to risk perception, risk identification, risk assessment and risk management. Two open-ended questions were asked of each executive as follows: “How do you manage your organization’s operational risks?” and “What are the available tools and techniques in your organization for managing the risks?” The responses are presented here in their own words.
or disease, place and means of accident and investigation information. This form is purely to record accidents or serious harm-related information. Another type of form was also found which is given the caption ‘Record of Accident or Incident Not Causing Serious Harm’. This form is recommended by OSH for an organisation’s own benefit to record the incident for further reference for minor injuries which are not mandatory to be reported to the relevant authority. Case A uses one identical incident-reporting document which includes a provision for recording near-miss/near-hit/minor injury events. The document is known as “The First Notebook” which is supposed to be used to record detailed information about the event where first aid is enough treatment. Again, this document is only for health and safety purposes. No other forms or documents are found which are used to record other operational disturbances.

### Table 1 Summary of the risk perception and risk assessment measures

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<th>Perception of operational risks</th>
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<th>In Case B</th>
<th>In Case C</th>
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<td>Available tools and techniques</td>
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We finally reviewed the safety manuals provided by the organizations. First of all, some key terminologies were studied that are used in the manuals in which the definitions of accident, incident and hazard are stated as follows: “Accident means an event that causes any person or property to be harmed, injured or damaged”; “Incident means a situation which had the potential to cause harm, injury or damage to persons or property (near misses/near hits)”; “A hazard is in actual or potential cause or source of a) serious harm; b) harm (being harm that is more than trivial, the severity of whose effects on any person depend on other things, and on the extent or frequency of the person’s exposure to it) or c) harm that does not usually occur, or is usually not easily detectable, until a significant time after exposure to the cause or source”. Reviewing the terminologies, we can understand that these relate to the harm, or potential to harm, mostly human assets and to some extent physical assets. This means that other types of incident or operational disturbance such as absenteeism, material shortage, machine malfunction, delayed supply from the regular supplier and so on, are totally ignored in the existing hazard identification, assessment and management. In essence, the organizations are found to lack appropriate tools and techniques needed to deal with operational disturbances and their associated risks. In addition, they did not appear to have any systematic approach for self-assessment which would enable them to identify the risk determinants for their businesses. However, this was not the case for occupational health and safety issues, where the studied organizations were found to be in a relatively better position. The case studies confirmed that all the organizations have well-written Health and Safety Manuals that comply with OSH regulations in New Zealand [49]. In the manuals, stepwise comprehensive descriptions about hazard identification, assessment and management procedures are in fact available. It is noted again that almost all are purely related to the health and safety of the employees. However, a significant gap between written procedures and practical applications is revealed in the majority of the organizations studied. A relatively weak safety culture was found, which included the reluctant attitude of employees to stringently follow the safety instructions, inadequate and casual use of protective equipment, and inadequate motivation to collect and share all health and safety-related information. In conclusion, although almost all organizations try to follow, or at least have documented procedures, to ensure that they are maintaining occupational health and safety systems for their employees, there is a substantial gap in the actual day-to-day application of these systems. It is also true that while talking about hazards and risks, the mindset of management is focused entirely on the health and safety issues alone and that their knowledge and practice of enterprise-wide risk management was found to be very limited. With their existing practices and strategic measures, they could not identify the actual risk determinants affecting their organizations, and neither could they identify the associated risks arising from these. Based on the findings, this research finally concludes that manufacturing organizations of the studied category only deal with occupational health and safety issues while they claim that they implement risk management.

### Other findings

Training for managers in up-to-date knowledge of new technology and new developments was found to be very limited. The managers’ scientific or technical knowledge of risk and reliability assessment was found to be remarkably poor. Thus, weaknesses in risk perception lie in the organizational mental model. Indeed, managers tended to lead their organizations by applying their acquired experience and knowledge, which is found to be inadequate in the context of operational risks. They do not have cost information about past accidents. They do not record day to day operational disturbances, their resulting lost time and other losses. In conclusion, a gap is found between risk perception and strategy formulation. Fact based information collection is missing. The research identifies that detailed disturbance-related data are not collected by the organizations. Therefore, scientific judgments or estimations of actual or potential risks
are not made, which is likely to produce erroneous prioritization. So, a gap is prevalent between strategy formulation and strategy implementation. The research also identifies that there are substantial weaknesses in the organizations, in terms of developing a healthy culture to manage and control operational risks. For example, employees smoke inside the factory despite a clear prohibition (e.g. a billboard reading “Smoking is strictly prohibited inside the factory”). They are reluctant to wear personal protective equipment, the operators are not cleaning and lubricating their machinery regularly even though they are supposed to do so, and the supervisor is not monitoring the outgoing products stringently, resulting in defective products going to the customers. The fact is that there is a gap between what they are doing and what they supposed to do, which results in a failure of the strategy at its implementation stage. It can be concluded that there is a gap between implementation, and the recognition and resolution phases. The research then finds that recognition of operational risks is substantially weak. None of the organizations have adequate information to identify actual losses resulting from the disturbances. In the context of information sharing, a major weakness is found in the data collection and information sharing process. The study reveals that all organizations collect and record only the accident/injury-related data using their existing incident reporting forms. However, the forms do not contain any information regarding the lost time and associated costs involved in an accident. Their decisions are biased significantly by the immediate business needs. For example, management may not hesitate to change the planned production schedule to satisfy its preferred customers even though it may dissatisfy the employees (or staff or other customers) or it may result in significant downtime and have other consequential effects due to the rescheduling. This situation was frequently observed in the case organizations. Preventive maintenance is not established even though there are frequent breakdowns and machine malfunctions in couple of organizations. Thus, the recognition and resolution of risk determinants are found to be substantially weak. Therefore, a gap is observed between recognition and resolution of risk determinants, and assessment of risks. Assessment of potential risks resulting from an event requires knowledge of the probability of occurrence of the event and its consequential effects. The research finds that the studied organizations lack the people with the expertise (with sound scientific knowledge of applied statistics) to assess the potential risks. It is also found that none of the organizations applied any advanced tools or techniques for risk assessment purposes. Managers were found to be completely ignorant about FMEA, FMCEA, FTA, ‘What if’ analysis, and so on. Moreover, they were not aware of the need to manage operational risks. However, the majority of the managers were found to be familiar with HAZOP and HACCP even though they applied these concepts purely for identifying health hazards. None of the managers have taken specialized training on risk management; they have not participated in any risk management-related conferences or symposia in their professional life. Neither had they attended any formal training or in-house seminars by external consultants to become familiarized with advance tools and techniques for risk management. They possess abstract or inadequate knowledge about risk management. Thus, a gap between the assessment phase and perception phase in the context of operational risks exists in the organizations.

The results from the study confirm that there are some gaps in understanding and practice of risk management, risk assessment in particular. According to the findings, it can be concluded that the proposed model is valid. The organizations follow the five steps for risk assessment but cannot be successful because of the gaps discussed above. It is noteworthy to mention that proven statistical approaches to manage pure and predictable risks cannot be fully effective in managing the operational risks which are associated with disturbances; the majority of which are caused by chance and by idiosyncratic factors. To be successful in managing operational risks, the manufacturing organizations need to make major organizational and cultural changes. Traditional quality or risk management alone could not be successful in managing the operational risks, even though they could significantly reduce some of them. We propose a framework in this paper to be followed for being successful in operational risk management.

V. A COMPREHENSIVE FRAMEWORK FOR RISK MANAGEMENT PROCESS

To bridge the gaps discussed in the previous section, an organization needs to significantly change its organizational culture. Otherwise, it will be difficult for it to implement any risk management approach. We propose a framework composed of certain guidelines to reach the top level of performance with regard to the approach for risk management. An organization should assess its existence level of risk management practice first and then to take necessary step to enhance its level to the next higher. For this, it should follow the operational risk management index (ORMI) developed by the authors. The ORMIs with certain steps and levels are depicted in Figure 2. First of all, an organization should follow certain steps to identify the strengths and weaknesses of its functional domains. Five aspects need to be ascertained to conduct effective analysis and decision making: i) the quality of the disturbance related information; ii) the deployment of this information into the decision making processes; iii) the purposeful utilization of the information (risk assessment purpose in this case); iv) the strategic implementation of decisions, and v) the constant monitoring of the information and control loops. In order to measure these aspects, the developed ORMI concept can be utilized.

The six ORMI levels are defined as:

Level 1: Identification- At this level, an organization is able to identify quantitative and qualitative information per disturbance, indicating immediate time lost for the disturbance and immediate consequential effects for this. It will be able to locate root causes and affiliated functional domains. In this phase, it is necessary to identify risk or hazard factors associated with the system. Classic risk management basically starts with risk or hazard identification [9]. Similarly, this research proposes that an organization needs to first identify the potential disturbances associated with its operational activities.
Minimum requirements of this level are: clear perception about the operational risks and structured methods for collecting disturbance-related data. If these minimum requirements are not fulfilled, the organization will not be able to identify risk determinants and monitor system performance.

**Level 2: Development** - The organization is able to establish formal feedback loops (forward loops for assessment purpose and backward loops of causal information), and constantly disseminate appropriate information to the particular destinations. At this level, the current status of the organization in the context of its exposure to disturbances should be established even though it will not be able to assess the actual risks without further analysis. Minimum requirements are allowing information flow without disruption, ensuring the right information is available to the right destinations, and constant assessment and improvement of feedback mechanisms. Without fulfilling these requirements, the organization will not be able to ensure error-free risk analysis.

**Level 3: Measurement** - The organization is able to scientifically measure the consequential effects of disturbances. The minimum requirements of this level are: basic mathematical knowledge and stratification ideas including the Delphi technique and brainstorming techniques (to capture intangible consequences).

**Level 4: Assessment** - The organization is able to assess the risks associated with the disturbances. The minimum requirements of this level are: basic statistical techniques and rational judgement. These will allow the organization to identify the most significant and least significant disturbances in term of their immediate consequences.

**Level 5: Analysis** - The organization is able to prioritize the action programme for mitigating, controlling or managing the risks. Minimum requirements at this level are: advanced statistical techniques and standard reliability analysis techniques (e.g. FTA, ETA, and FMEA). These will allow the organization to rank the disturbances and prioritize the action plans. At this level, the organization will be able to, not only eliminate or mitigate the risks, but also analyze the system performance, locating the root causes behind the disturbances and their affiliated functional domains.

**Level 6: Adaptation and improvement** - The organization is able to learn from the past events in establishing control mechanisms and evaluating further risks. It will be able to eliminate, control and manage the anticipated risks as a part of a continuous learning process. At this level, the organization will know the root causes of the disturbances, their origins and thereby it can control the causes not to happen again in future. Moreover, it will be able to develop control mechanisms and knowledge about the enablers/controllers and conditions of the functional domains. Thereby, it will be able to improve its risk management approach continually.

It is noted that in order to qualify for ORMI level \( n \), the requirements at level \( n-1 \) and lower, need to be fulfilled. For example, an organization first needs to know what type of operational disturbances are occurring in its system before making a decision about establishing formal feedback loops to manage these. This means that the sources of a disturbance, relevant interested parties and type of information needed, are required to establish a meaningful feedback system. The requirements for each level are shown in Figure 1. It is important to know the requirements in detail, to establish a structured path to move forward with a strategic approach. The developed model and the comprehensive framework in this research are, in fact, able to show that path.

**VI. CONCLUSION**

In this paper, an attempt has been made to discuss the key aspects of operational risk management in manufacturing organizations. A conceptual model is developed to discuss the key factors associated with risk assessment and outline the gaps in risk assessment process. In-depth case studies were performed at five manufacturing organizations concerning the key aspects of risk assessment. The findings of the study are presented with the objective of focusing on most implementation issues of risk management. Finally, a comprehensive framework is developed in light of the conceptual model and experience gathered from the empirical study. The framework is claimed to be comprehensive as it includes almost all major aspects of risk management found in the literature. It is also novel and hopefully simple to follow. Further study comprising a large number of firms can provide additional information on the implementation of risk management approach discussed in this paper.
ACKNOWLEDGMENT
The authors are grateful to the University of Auckland for financial support to conduct the research.

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