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PQCDSM-Logic in Maintenance (TPM) and Mountaineering

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Abstract: TPM is the foundation for JIT (Just in Time) and Lean Manufacturing and forms the basis of JIT or on-time delivery. The goal of TPM is to improve equipment effectiveness and optimize equipment performance, namely PQCDSM (Productivity, Quality, Cost and Delivery, Safety and health, environment, and Morale). Many producers have tried to transform their production system to a JIT or Lean production system with the aim of increasing productivity and quality, but thus far with little success. This contribution shows how trekking and climbing tours can be used to illustrate the application of PQCDSM-Logic in mountaineering and how this can be transferred to logistics and maintenance practice. The background is the author's decades of experience with expeditions, trekking and climbing tours, TPM implementations and interviews with numerous experts. There are many similarities between the application of PQCDSM-Logic in mountaineering and in logistics and maintenance practice, which will help both in operational practice in industry and in high mountain tours, especially regarding safety in a changing environment. Presented is the extrapolation from mountain climbing to TPM and the importance of leadership for a successful (summit climbs and the like) transformation of the production system to a JIT or Lean production system.

Keywords: environment; equipment; leadership; logistics; PQCDSM; mountaineering; safety; Total Productive Maintenance

1 INTRODUCTION (LITERATURE REVIEW)

As early as the 1960s and 1970s, some manufacturing sectors in the West were already being outperformed or partially eliminated by Japanese competitors (optics, watchmaking, shipbuilding, and consumer electronics). After the first oil crisis in 1973 and, in particular, the second oil crisis in 1978, the Japanese automotive industry was also perceived to be a serious competitor. With great effort, especially through the implementation of rationalization and automation measures, Western manufacturers tried to become competitive again in the 1980s.

The fundamental basis of Japanese success was little understood. Although there were already some descriptions of Japanese production systems, this had little impact on industrial practice, e.g., the 1981 publications on the *Productivity Machine in Japan* by Hall [1] and *Japanese Factories Work* by Hayes [1] and on the *Toyota Production System* by Shingo 1981 [3], Monden 1983 [4] and Ohno 1988 [5]. Other publications on this topic included *Japanese Manufacturing Techniques* by Schonberger 1982 [6], *The SMED System* by Shingo 1985 [7], *Japanese Just-In-Time production system* by Reda 1987 [8], *and Total Productive Maintenance* by Nakajima 1988 [9], which were also without significant resonance in the manufacturing industry.

It was not until the publication of *The Machine that Changed the World* in 1990 [10] that Western manufacturers had a significant wake-up call and subsequently made frantic efforts to convert their production to a just-in-time production system. However, only few were successful. A boom of translations of Japanese books on production methods into German took place, such as *Six Sigma* 1990 [11], *Kaizen for Quick Changeover* 1995 [12] and *Introduction to TPM* 1995 [13], but after the Japanese real estate bubble burst, manufacturers returned to their traditional processes.

When the Japanese car company Toyota replaced Ford as the world's second-largest automaker in 2003 [14], the automotive industry finally woke up from its deep sleep. This was followed by hectic activity, with many companies trying to change their production system to Lean production or derivatives of TPS with TPM methodology and excellent manufacturing as their goal. As a result, the last two decades have been filled with numerous attempts to apply these concepts in companies. However, this has only been partially successful and has, in fact, often completely failed.

The main reason why most companies fail in implementing Lean is presented in this paper. In 1985, Shigeo Shingo stated that "60 to 70% of success comes from people" and 30 years later this still had not changed [15]. The results of a study conducted decades ago by Harvard University in the US on 400 different companies showed why most transformations had either partially or completely failed. The most important reason for failure was the lack of comprehensive leadership. Other reasons included the lack of an effective decision-making process as well as a lack of direction and vision in executing the transformation [15].

Numerous studies show the reasons for the failure of Lean. They revealed that Lean implementation failures mainly fall into two common failure mode categories, involving ‘Top Management Leadership’ and ‘People/Employee’ issues. "Almost all Lean experts agree that the main reasons for implementation failures involve senior management and ownership". Leaders are, after all, ultimately responsible for everything that happens within a company [16].

The track record for a successful implementation of the Lean methodology is spotty at best. Some studies state that failure rates for Lean programs range between 50 percent and 95 percent [17].

Achanga et al. [18] describe four main key factors for the implementation of Lean manufacturing in an SME environment: leadership and management, finance, skills and expertise, and the inherent culture of the organization. “Leadership and management commitment are the most critical factors in determining the success of a transition to Lean”. According to one study, the success or failure of Lean transitions strongly depends on the company's approach and on whether it has developed its own Lean philosophy [19].

The track record for implementing Lean is poor. According to studies, more than half of all Lean implementations fail because of corporate culture: No strategy, e.g., no clear responsibilities, no metrics, and no executive commitment. Lean requires top-down leadership [20]. The success of Lean implementation depends on top management commitment and leadership, the attitude of the employees, resources, and organizational culture [21].

For years, one major problem with Lean implementation, as indicated by the numerous surveys and studies on the topic, has been its overwhelmingly high failure rate. The results of Lean implementations are discouraging. For example, a 2007 Industry Week study found that nearly 70% of all US plants were using Lean, but only 2% were meeting their goals. There are many other literature reviews and case studies about the high failure rate of Lean and, after more than 30 years, it is still not getting any better [22].

The successful implementation of Lean can bring enormous benefits to any company, but in practice the failure rate is very high. An analysis of existing literature from the last 20 years and further analysis of studies from the last 10 years show: leadership from top management, the organizational culture of the company, effective communication, and knowledge and mindset remain the most important factors for a successful Lean implementation [23]. As with any major organizational change, it is necessary for senior management to be committed to reducing headwind and minimizing employee resistance [24].

Only few companies implement Lean manufacturing correctly and there are also a number of difficulties that inhibit the success of these initiatives, e.g., logistical and planning challenges as well as behavioural concerns. Some common challenges include, on the one hand, lack of support from senior management and, on the other, inadequate employee training, limited workforce, lack of appropriate tools, failure to monitor progress (insufficient performance data), problems arising from the implementation of multiple changes at once, and the difficulties caused by replacing established work practices (cultures) [25].

A study on the implementation of Lean in small to medium-sized enterprises (SMEs) reveals that the real problem for achieving Lean success was not a lack of commitment on the part of top-management, but rather their ignorance regarding what they should commit to, i.e., it was a knowledge problem rather than a commitment problem [26]. For SMEs with limited resources, management knowledge is especially important when implementing Lean. There are two categories of insufficient manager Lean knowledge in terms of failure factors [26]:

- Level 1: Ignorance, i.e., a complete lack of knowledge, of the following: Benefits of Lean and how to implement it as well as how Lean concepts have developed.
- Level 2: Erroneous knowledge of Lean implementation, i.e., unawareness that: Lean is not purely a manufacturing tool, belief that Lean will be of no benefit outside of mass production, is for process improvement only, is implemented by process engineers and consultants, i.e., and there is no need for 'me', the manager, to be involved.

It is not helpful to simply blame top management for these types of failures. However, the references given are only a very small selection on the topic of "no top management commitment". It remains to be seen whether "no top management commitment or "top management ignorance with either a complete lack of knowledge about Lean or erroneous knowledge about the implementation of Lean" are more damaging [26].

No commitment or no idea - Catch-22 or debacle? There are real reasons for failures and their causes. However, top management is the key person and the one who makes the decisions and ultimately bears overall responsibility.

2 TOTAL PRODUCTIVE MAINTENANCE (TPM) AND PQCDSM

Total Productive Maintenance (TPM) is a management system, which was developed by Seiichi Nakajima [9, 13] in Japan and implemented for the first time in 1971 to optimize operational processes through the creative participation of all employees. TPM is the foundation for the JIT (Just in Time) production system, which is dedicated to producing the right part at the right time and of the right quality. Reliability and the synchronising of production is indispensable. TPM involves productive maintenance, which is the responsibility of all employees and performed in small group activities, and equipment maintenance, which is performed on a company-wide basis. A dual goal of TPM is zero breakdowns and zero defects, which form the basis of JIT or on-time delivery.

With increasing robotization and automation, the greater the shift of the production process from workers to interconnected machines and the larger the role played by the equipment itself. The purpose of TPM is to enhance the effectiveness of the equipment and maximize its output by optimizing the Key Process Indicator's (KPI's) PQCDSM: *Productivity, Quality, Cost, Delivery, Safety (and health, environment), and Morale.* PQCDSM is dependent on the condition of the equipment and can be individually adapted to suit the requirements of the respective organization implementing it. To achieve this, they must first define and set targets of each of the areas of PQCDSM by considering all losses and bottlenecks that could potentially affect plant performance. TPM also aims to eliminate the 'big losses' to achieve an increase in Overall Equipment Effectiveness (OEE) [9, 13, 7, 12]. This is the only indicator that effectively combines the measures Availability, Performance, and Quality of a site.

Suzuki cites, for example, PQCDSM (Productivity, Quality, Cost, Delivery, Safety, Morale) improvements for early TPM implementers in Japan, see Table 1 [27]. Successful TPM implementations are driven by leadership commitment and support, high motivation and involvement of employees, sufficient resources, and communication [12, 13, 28].

A PQCDSM-process board of an automobile manufacturer is shown in Fig. 1 [28].

TPM Excellence Awards of JIPM, who, since 1994, has been evaluating and honouring enterprises or factories

throughout the world with their award for "Operational Excellence and Maintenance Excellence", with the aim of encouraging further progress and development. In the TPM Award Assessment Achievement Sheet for the TPM Excellence Award outside Japan, the PQCDSM categories are represented according to the TPM start or last award, current status, and targets of the company [29].

According to Nakajima, the application of TPM must be tailored to the individual needs of the company. Each company must develop its own action plan according to its problems, industry, type, and condition of equipment [9].

Table 1 PQCDSM-improvements for early TPM implementers in Japan [27]

- **P – Productivity:**
  Net productivity up by 1.5 to 2.0 times.
  Number of equipment breakdowns reduced by 1/10 to 1/250 of baseline.
  Overall plant effectiveness 1.5 to 2.0 times greater.
- **Q – Quality:**
  Process defect rate reduced by 90%.
  Customer returns/claims reduced by 75%.
- **C – Cost:** Production costs reduced by 30%.
- **D – Delivery:** Finished goods and Work in Progress (WIP) reduced by half.
- **S – Safety.**
  Elimination of shutdown accidents.
  Elimination of pollution incidents.
- **M – Morale:** Employee improvement suggestions up by 5 to 10 times.

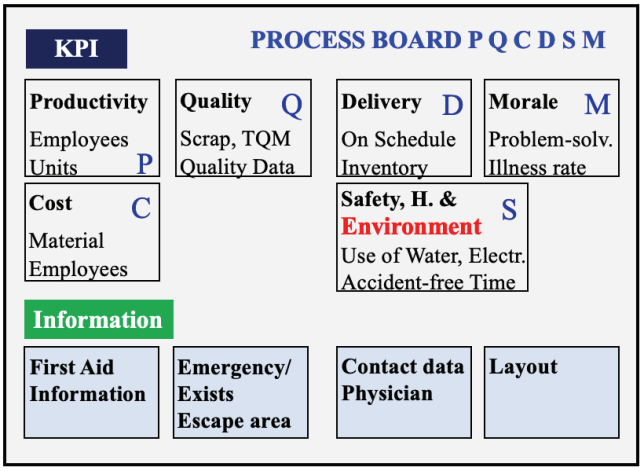

Figure 1 Process Board P Q C D S M an automobile manufacturer [28]

3 MOUNTAINEERING IN A CHANGING ENVIRONMENT AND PQCDSM

3.1 Mountaineering in a Changing Environment

The great outdoors in the high mountains is associated with potential risks and danger: rockfalls, avalanches, crevasses on glaciers, landslides, extreme cold, and dramatic weather changes. These can be minimized by appropriate equipment, cautious route selection, and adequate knowledge of the risks [30, 31, 32].

Mountains influence weather and weather phenomena in mountainous regions can be quite spectacular and often extreme. In recent decades, conditions and weather patterns have changed, sometimes significantly, especially in the high mountains of Asia, South America, and Africa. Landslides and regions vulnerable to landslides with loose, steep sandy gravel slopes; the possibility of floods and heavy rains in the semi-arid cold steppe that can wash away complete villages, the risk associated with heavily swollen river crossings; exposed ridges, or slippery ground; the increased danger of crevasses and ice breakage; crossing areas that are abandoned by climate refugees because of drought, cold spells, rock falls, minor earthquakes, and volcanic eruptions – all phenomena that the author has experienced himself [33, 34].

There are, on the one hand, known risks that can be successfully managed with proper planning, and, on the other, completely unexpected hazards (unknown unknowns) such as the October 2014 cyclone in Nepal that brought with it blizzards, unusually strong snowstorms and avalanches, a disaster that killed at least 43 people in the Annapurna/Thorong La pass area alone [35]. The unavoidable transportation to reach the tour start can be a risk, e.g., travelling along rocky roads that resemble the bed of a mountain river or having to fly to airports where landings are extremely hazardous, e.g., Lukla's airport in Nepal, called "the most dangerous airport in the world", due to the many accidents with numerous fatalities among passengers and crews [36]. Once at the destination, a cook, helpers, porters and/or pack animals are required, whose quality is vital for the successful outcome of an expedition?

For assessable risks, the necessary equipment is required: clothing, mountaineering boots, rope, crampons, ice axe, climbing harness, carabiner, helmet, tent, etc. In the high mountains, altitude sickness can occur from an altitude of 2000 to 2500 meters, if the ascent is too fast [37, 38, 39, 40]:

- HYPOXIA (oxygen deficiency) massively impairs judgment, slows down all reflexes and clouds the sense of reality (Hypoxia symptoms vs oxygen saturation [37] Table 2).
- Acute Mountain Sickness (AMS) occurs mainly at altitudes above about 2000 m and is the most common form of altitude sickness (leading symptom headache).
- High Altitude Pulmonary Edema (HAPE), 2/3 of all HAPE cases occur between 3000 and 4500 m above sea level (leading symptom sudden loss of performance).
- High Altitude Cerebral Edema (HACE), although is rarer than HAPE, is often fatal, and symptoms can progress very rapidly to coma and death (leading symptom ataxia).
- Combined high altitude edema: HAPE and HACE very often occur simultaneously. The course of this combination is very often fatal.

Good acclimatization is therefore essential and oxygen saturation should be monitored by a pulse oximeter throughout the tour [34, 37, 38, 39, 40].

Besides a lack of acclimatization, another risk factor is a person's individual vulnerability. During an expedition in 2017, a team member had to be flown out by rescue helicopter from a high plateau at 5200 meters due to his very poor general condition and oxygen saturation of only 51 percent. From 50 percent O_2, a rescue helicopter is used in Nepal, if

it can be requested with a satellite phone and the assumption of payment by an insurance company is proven. The author himself was able in 2018 to descend very quickly from 4900 meters to lower elevations after a night with 54 to 49 percent O_2 [34, 38]. This shows very clearly the safety aspect and the logistics required in mountaineering. With the support team, all equipment, and a food supply for several weeks, including beyond the envisaged tour end, must be provided, as replenishment is not possible.

Table 2 Hypoxia symptoms versus oxygen saturation [37]

Arterial Oxygen Saturation Levels / Hypoxia Symptoms Versus Altitude			
Altitude	O_2 Saturation	Stages of Hypoxia	Symptoms
0 – 10,000 ft 0 – 3048 m	98 – 90 %	Indifferent	• Decrease in night vision
10,000 – 15,000 ft 3048 – 4572 m	90 – 80 %	Compensatory	• Drowsiness • Impaired judgement, coordination, efficiency
15,000 – 20,000 ft 4572 – 6096 m	80 – 70 %	Disturbance	• Impaired flight control • Impaired handwriting, speech • Decreased coordination
20,000 – 25,000 ft 6096 – 7620 m	70 – 60 %	Critical	• Circulatory and central nervous system failure • Convulsions • Cardiovascular collapse • Death

3.2 Mountaineering in a Changing Environment

The TPM safety, health and environment pillar is particularly significant. "Ensuring equipment reliability, preventing human error, and eliminating accidents and pollution are the key tenets of TPM" [27, p. 323] and implementation of the TPM safety, health and environment pillar focuses on identifying and eliminating safety and environmental issues. According to the Heinrich Principle (Heinrich 1980), for every 500,000 safety incidents, there are 300 'near misses', 29 injuries, and 1 fatality (see Fig. 2). In studying industry accidents, Heinrich found that 88 percent of accidents were caused by unsafe actions of people, 10 percent were caused by unsafe physical conditions, while he considered the remaining 2 percent to be "acts of God" [41, p. 63], see Fig. 2. The Heinrich pyramid was further developed in 1966 by Frank E. Bird from an analysis of 1.7 million accident reports from nearly 300 companies.

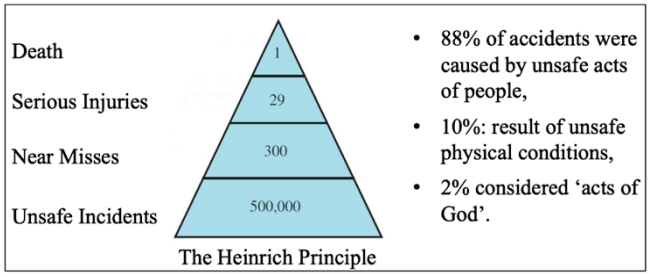

Figure 2 The Heinrich Principle of accidents [41, p. 64]

Environmental safety is increasingly becoming a focus of TPM implementation. Production management in the 21st century will not be effective if environmental issues are ignored. An environmental management system (EMS) that integrates environmental issues into manufacturing systems must be established. In other words, environmental safety goes beyond simply eliminating accidents. In today's manufacturing environment, environmental safety includes reducing energy consumption, eliminating toxic waste, and reducing raw material consumption. The environmental management system is thus an integral part of production management and should be implemented via TPM. This consists of environmental education, product, and equipment development, implementing improvements to reduce environmental aspects, and considering environmental impact. It is considered appropriate to develop these issues along the traditional TPM pillars [41, p. 65-66].

Safety, health, and environment have a significant importance both in mountaineering and as a pillar of TPM. How the most beautiful and remote high mountains are polluted shall not be further discussed here [33, 34]. Table 3 shows the experience during tours/expedition in high mountains with the application of PQCDSM logic in mountaineering and the possible impact on maintenance practice. [33, 34].

Table 3 PQCDSM-Logic - Mountaineering facts [33, 34]

P	– Excellent performance of support team (guide, cook, helper, porters, horse handler). – Public transport – a nightmare – Hindu society
Q	– Excellent quality of support team. – Excellent meals three times a day, even at elevations of up to nearly 5850 m.
C	– Total costs, no savings on life-saving equipment – Trip, Equipment, Energy, Insurance, Satellite telephone, Pressure bag.
D	– Overall organization – nearly everything on time, – But no plane because of bad weather, adventure public transport
S	– River crossings, cavasses, glaciers, insurance, falling, rock falls, crampons, – High altitude sickness, rescue helicopter, exposed crest, slippery ground, pulsoximeter – Waste management, mismeasurement – Safety is the maintenance of peace of mind
M	– Excellent moral of support team and of climbers (snowstorm etc.)

4 MOUNTAINEERING, MAINTENANCE AND LEADERSHIP

4.1 Maintenance and Mountaineering

According to Nakajima [9], equipment maintenance means equipment health. In other words, each person is responsible not only for his own health, but also for the health of the equipment he uses. There are many similarities between the application of PQCDSM logic in mountaineering and in logistics and maintenance practices that will help in operational practice and high-altitude tours, especially in terms of safety.

An expedition around remote Dhaulagiri and the ascent of Thapa Peak 6076 m in 2017 and the ascent of Mera Peak

2018 m demonstrate the application of PQCDSM logic in mountaineering and the transfer to logistics and maintenance practice, what do and what to consider (see Tab. 4) [28, 34], Fig. 3 shows the mountaineering route to Mera Peak 2018 [34].

Table 4 Maintenance & Mountaineering: and the transfer to logistics and maintenance practice [28, 34]

There are no minor things. - *"It's the little things that make the big things possible", J. W. Marriot.*
You are responsible, no one else is to blame. - *Defined tasks and responsibility.*
There are risks, known and unknown. - *Implement Risk management, emergency plan.*
There is always an unexpected first time. - *Risk management, but learn, to avoid same error a second time.*
Meticulous preparation always. - *Proper SOP, process description, training, maintenance manuals.*
Common sense (existence doubtful). - *Think about things from the ground – Aristoteles quoted that common sense is not so common.*
Strange / "clever" actions. - *Think ahead, safety first, no dangerous shortcuts.*
Communication saves lives - Silence kills. - *Digital communication speeds up, define reporting line.*
Supplier/Support. - *Spare parts available/at supplier, reliable supplier.*
Knowledge, skills, training, education, talent, good base. - *E. g. execute recertification, training.*
Exercise, exercise, exercise. - *Train evacuation in plants (to seldom done), instruct process sheets.*
Appropriate health information, visual, O_2 measure. - *Emergency/ first aid information. e. g. on process board.*
Equipment – know how to use it, train (pressure bag). - *Proper instructed and practiced.*
Saving money on equipment, higher risks follow. - *Equipment wears down, risk of break downs, savings damages occur.*
Adopt timetable and speed to abilities and elevation / environment. - *Provide buffer time.*
Know/Look for early warning signs. - *Early warning systems, monitoring process parameter e. g. vibration.*
Prepare known unknowns. - *Safety budget in case of emergency; alternative plan e.g., supply & production.*
Do not try to be clever / take unnecessary risks. - *Always Consider consequences.*
Hang on when it hurts, know when to stop, 110/120 bpm. - *Improve Resilience, consider cost sunk fallacy.*

Safety is the highest priority in mountaineering. The goal is to climb to the summit, but even more important is to return safely. Logistics are also crucial for successful mountain climbing. This also applies to companies. The ultimate goal is to sustain the company over the long term with reliable supply chains.

Figure 3 Mountaineering Route to Mera Peak 2018 [34]

4.2 Mountaineering and its Significance for Corporate Leadership

The fundamental basis of Japanese success was at first poorly understood and then largely ignored. Fig. 4 shows the first publication in Germany in 1982 on the way of production in Japan [43]. The EU-Japan Centre for Industrial Cooperation, a joint venture established in 1987 by the European Commission and the Japanese government (METI), promotes cooperation between the EU and Japan, e.g., training programs and Lean master classes on Lean management [44] and 'Lean in Europe visits' [45].

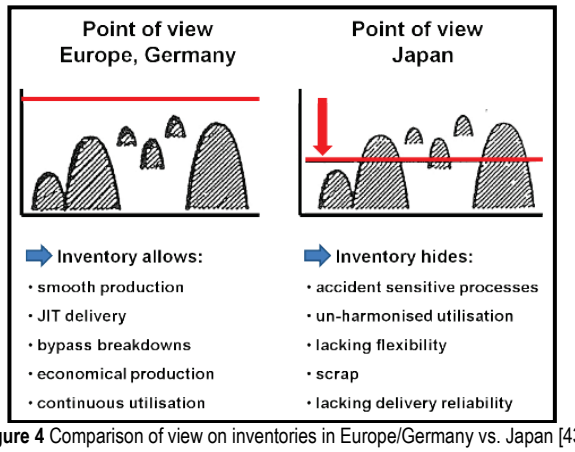

Figure 4 Comparison of view on inventories in Europe/Germany vs. Japan [43]

As noted previously, the numerous attempts over the past three decades in the West to transform companies to Lean production have only partially succeeded or often failed. For example, in over 30 years, the exceedingly high number of efficiency and quality campaigns by a well-managed automobile manufacturer have not led to any great success [46]. Leadership is the basis for excellence [47] and, as already

mentioned, the main reason for this lack of success is an absence of leadership commitment - Lean requires top-down leadership: no commitment/no ideas - Catch-22 or debacle?

Excellence in production is a goal for the industry with leadership as the foundation. Expedition and climbing leadership require important leadership skills. Reflections on my experiences in expeditions and climbing tours made me aware of the parallels between my high mountain tours (since 1973) and my industrial practice with Japanese production methods/Lean (since 1982). Both high mountain tours and the transition to Japanese production methods/Lean require planning, stamina, goal setting, commitment, calculation, teamwork, conviction, and endurance [33, 34, 38].

High mountain tours require an achievable goal. Common to high mountain tours and industry is the setting of a vision and the provision of support to employees by mountain/company leaders in achieving that vision. Most important, of course, is the safety aspect: sustainable survival of the company and of the climbers:

> *"In principle, the mountaineer's work is simple: "To win the game he has first to reach the mountain's summit, "said George Mallory, who took part in Britain's first three attempts on Everest in the 1920s. "But, further, he has to descend in safety" [48].*

Company leaders often use examples from mountaineering or sports, or they hire the relevant people to motivate their employees, in order to achieve their objective - world class manufacturing, which is synonymous with the victory of reaching the summit or a championship win. All require teamwork, a shared goal, and the staying power to overcome difficulties. As with mountain climbers, an organization's vision must be linked to a clear route to the summit or long-term goal. Once the vision and route are established, what happens next depends largely on the complementary actions of leaders.

My numerous expeditions and climbs highlighted key powerful characteristics and skills for leading such tours [33, 34, 38]. These qualities also fit very well for managers in Industry:

- Humility and partnership: mountaineers are especially aware that they may be exposed to forces of nature.
- Stamina, resilience, and determination: in the endurance sport of mountaineering, a goal can be achieved in hours, days, weeks or even months.
- Adaptability: they adjust their leadership style to rapidly changing conditions.
- Social intelligence and empowerment: they quickly establish positive interactions with stakeholders and provide a supportive space for growth and development.
- Trust builders: they help their clients to build trust in themselves and their support teams.
- Risk awareness and overcoming obstacles: act skilfully and safely under uncertain conditions, be well prepared, use checklists and overcome barriers.
- Big picture thinking: have a holistic view of the mission and be able to plan alternatives.
- Recognize and integrate what you have learned: learn from the most difficult experiences and share these insights with others.
- Practice patience, be grateful, and share your success.

There are now several works on this topic from business schools/universities, companies, and consultants. The Wharton School has developed Nano Tools for Leaders® with some similar criteria, i.e., lead like a mountain guide by adopting the strengths of mountain climbers [49].

Lessons from Everest show the role of collaborative leadership in a crisis situation and draw insights for business leaders. A collaborative leader creates a safe, clear, and cohesive environment for the group to work in, masters cross-boundary skills, including utilizing diversity in the group, and inspires the group through vision and character [50].

Mountaineering is like business leadership, in that leading a business or leading a rope team are both highly personal experiences. Success might be a result of superior planning, or it might also be just pure luck. As is the case for most mountaineering endeavours, the safety and success of a business rely on the strength of a team [51]. In fact, many of the required leadership skills in business can be developed while climbing mountains, namely, the necessity of practicing the art of patience, persistence, gratitude and sharing the success. [52].

Nine observations on leadership and teamwork from Mt. Everest shows there is power in having a clear goal with a hard deadline; that you must not be taken in by first impressions; that it is important for morale to frequently express your gratitude to your team, and that you should be aware that, although technology has its uses, it is only useful until it starts to detract from the mission. Some mountaineering teams are equipped with smartphones, cameras, smart watches, GoPro videos, and Wi-Fi and although this connects the team members to the outside world, it detracts from their connection to each other and their shared experiences. In this situation, technology can even be harmful as it brings with it distractions and misinformation and ultimately risks [53].

5 CONCLUSIONS

In mountaineering, everyone depends on each other for success and for their survival, and, to achieve this, tour leaders set their team a clear, definite goal. However, most companies do not have such a clear concept regarding their goals, even though creating one is the key to successful leadership. Therein lies the challenge. Lean production systems and the new development towards home offices require an adapted leadership culture [54, 55, 56].

Of the many similarities between the application of PQCDSM logic in mountaineering and in logistics and maintenance practice, safety should be given particular emphasis in both operational practice and high mountain tours. The most important goal in mountaineering is a safe return, while in industry it is the survival of the enterprise. However, the life span of companies has been decreasing dramatically for years. Furthermore, the endurance aspect, in particular, must be given far greater consideration.

The corporate life span has shortened dramatically in recent decades. The average length of time that US corporations remain in the S&P 500 stock market index has reduced from 33 years in 1965 to only 20 years in 1990. By 2026, the average length of stay is projected to be only about 14 years, and it is expected that about half of the 500 companies currently represented in the S&P will be excluded from the index within the next ten years [57]. Of the companies founded in Germany in 2015, the survival rate after five years was only 37.1 percent [58]. Due to this dramatically increased rate of change in the economic and technological environment, half of the large companies in the United States have disappeared since 2000 [59] and, according to a study by the John M. Olin School of Business at Washington University, it is estimated that about 40 percent of today's Fortune 500 companies will no longer exist by 2025 [60].

In addition to the lack of executive commitment described in the introduction, the lack of long-term direction for the transition to a Lean production system is the primary cause for failure. This is shown clearly by the over 30 years of failed efficiency and quality campaigns of automotive manufacturers [46] as well as by the results of VDI working groups (Association of German Engineers) [54, 55]. Although the change to Lean production is generally initiated relatively well, it is hardly followed up by top management, with the result that any achieved success will fade away over the next years. This happens not only once, but several times in wave movements over three decades.

For example, a company wins the business award of EFQM (European Foundation for Quality Management) for their achievements, but after some time all their success has disappeared due to a complete lack of attention by management. The benefits of the Continuous Improvement Process (CIP) were certified as a complete success by Lopez' office at Volkswagen (VW) in 1994, as it had led to a 21% increase in productivity and saved several billion Deutsche Mark, the German currency at that time. The goals for 1994 were 5000 to 6000 CIP workshops and the training of 800 CIP instructors, who would be responsible for the training of employees at VW and its suppliers [61, 62]. However, in spite of the good intentions and optimism, nothing survived from the implementation of Lopez's reforms at VW in the 1990s [46].

Mountain safety and long-term sustainable business development ensure survival in a hostile nature and competitive business environment, respectively. However, both require endurance, as no mountain can be climbed without endurance, and no sustainable change process can occur in businesses without long-term endurance. This is not a quick fix project, but a very long-term process lasting 10, 15 or even 20 years. Endurance is required over and over again.

The importance of endurance, or long-term development, is also shown by the quote from Guan Zhong (720-645 BC) [63]:

It takes ten years to grow a tree, but a hundred years to develop people.

十年□ 木, 百年□ 人.

"The best investment for one year is to grow crops; the best investment for ten years is to plant trees; the best investment for a lifetime is to educate people. What you gain from the growth of one year is grains; what you gain from the growth of ten years is trees; what you gain from the growth of a hundred years is talented high-quality people."

The meaning of this quote is that it takes time to educate people and develop them into productive members of our society. It is not a work such as growing crops or trees, where you can see the pay-off in a year or ten years. But it is a rewarding effort in which our society needs to invest.

But as long companies continue to set their direction in the form of quarterly reports, changes, such as the transition to a Lean production system, will be predominantly accompanied by many setbacks, failures, and patchwork.

In our fast-moving times, short-term profit beats the long-term, sustainable development of people & society!

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