

Automated Warehouse Shutdown: Dental Trey Case

Operation Risk Management and
Resilience

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Contents

Abstract	iii
1 Introduction	1
1.1 Plant layout and technologies used	2
1.2 Business Context	3
1.3 Customers information	4
1.4 Suppliers' information	4
2 Theoretical Understanding	5
2.1 Definitions	5
2.2 Models	7
3 Methodology	9
4 Synthesis of Findings	10
4.1 Incident description	11
4.2 Incident Impacts	12
4.2.1 Financial Impact	12
4.2.2 Operational Impact	12
4.2.3 Market Consequences	13
4.3 Summary	13
5 Discussion	14
5.1 Risk Management and Resilience models	15
5.2 Business Continuity Plan for IT Security Management	18
6 Conclusion	19
List of Figures	20

List of Tables	20
References	20
Annex	22

Abstract

This report examines the critical aspects of operational risk management and resilience, focusing on a significant disruption experienced by Dental Trey SRL, a prominent player in the Italian B2B dental supply industry. The case study revolves around the company's automated warehouse shutdown, a pivotal component of its supply chain operations, caused by a software update malfunction in 2017. The incident disrupted operations for weeks, resulting in considerable financial, operational, and market consequences, including revenue loss, diminished customer trust, and strained employee workloads.

The report begins with an overview of Dental Trey's business context, highlighting its automated warehouse, state-of-the-art inventory systems, and reliance on technological solutions to ensure efficient supply chain operations. It identifies the company's strategic use of SAP-driven automation and its vulnerability due to high interdependence on critical technological infrastructure. Through a detailed timeline of the incident, the report recounts the events—from the initial malfunction to the eventual resolution by an external consultant—and underscores the cascading impacts across financial, operational, and reputational dimensions.

The analysis incorporates theoretical models, including the Bow-Tie framework, Resilience Core Functions, and COBIT 5, to evaluate Dental Trey's risk management and resilience approach. The findings reveal notable gaps, such as inadequate preparedness for rare but high-impact events, limited employee cross-training, and insufficient business continuity planning (BCP) tailored to IT disruptions. Despite having basic reactive measures, the company lacked proactive and preventive strategies, exacerbating the incident's effects.

Key recommendations emphasize the need for comprehensive risk assessment frameworks, robust BCP integration, and enhanced IT security measures. Suggested interventions include scenario-based training, rigorous testing of software updates, implementation of redundancy systems, and alignment with international standards like ISO 22301 and COBIT 5 DSS04. Additionally, fostering a culture of preparedness and resilience through regular audits, drills, and stakeholder engagement is essential for mitigating future disruptions.

This report is a critical resource for organizations reliant on automated systems, illustrating the importance of balancing technological advancements with robust risk management practices. The lessons learned from this incident provide actionable insights into enhancing resilience and operational continuity in complex and high-stakes supply chain environments.

1 Introduction

Dental Trey S.R.L., based in Predappio, has been a stalwart in the Italian B2B dental supply market since its establishment in **1981 in Forlì**. With a robust catalogue of over **40,000 products**, it achieved a turnover of **46 million euros in 2023**. The company employs **72 people** and is organised into four business divisions.[12]

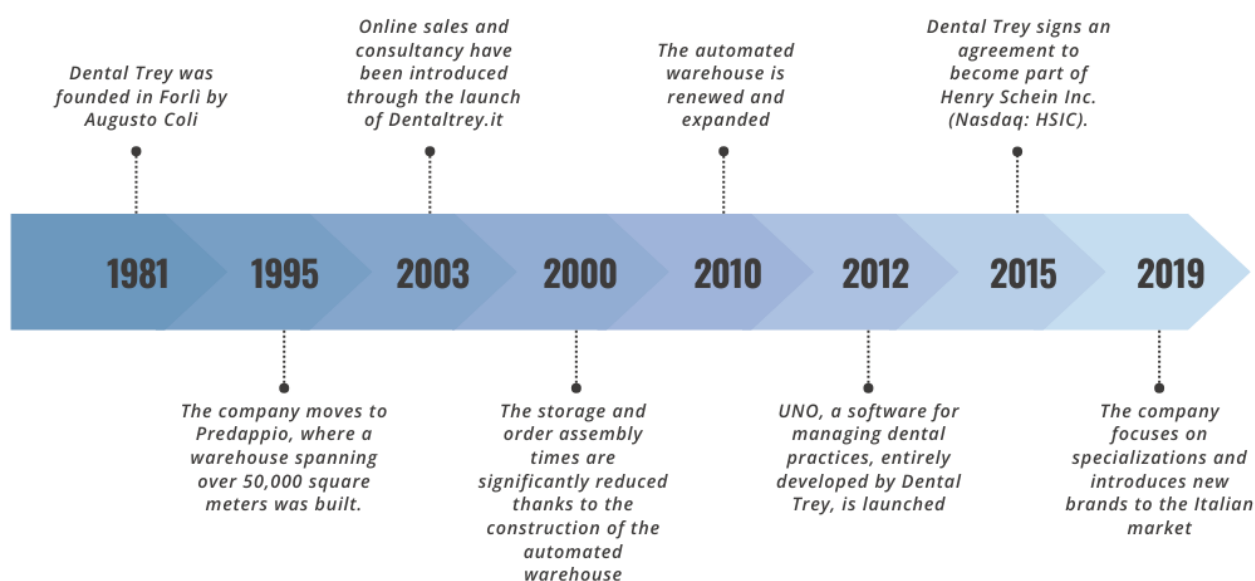


Figure 1: Timeline

The Consumables Division offers 40,000 products selected from **420 international brands** and, thanks to an automated warehouse, can process orders within 24 hours. Additionally, the sales network is supported by over **100 professional consultants** active across the country.

The Hi-Tech and Traditional Equipment Divisions provide complete consultancy, ranging from the initial project and free estimate to the definition, delivery, installation, testing, and after-sales support of dental equipment.

The IT Division manages the proper functioning of the **UNO management** software, which ensures daily direct contact between the company and its clients. Currently, over 93% of Dental Trey's software customers have subscribed to the annual support service, a tangible proof of the quality of the service.

Since 2015, Dental Trey has strengthened its position and fostered strong customer relationships by joining the Henry Schein Inc. group. With over 18,000 employees worldwide, HS group provides more than 1 million global customers with over 300 valuable solutions, helping them improve business success and clinical outcomes.

Henry Schein operates through a centralised and automated distribution network. Over 120,000 branded and private-label products are always available, and more than 180,000 additional unique products are available upon order.

1.1 Plant layout and technologies used

In 1995, the company moved to Predappio, where it built a warehouse of over 50,000 square meters. Over the years, it has been reorganised several times. The first automation in the warehouse was introduced in 2000, while in **2010** the full automated warehouse management was entrusted to Logicon, an IT company which develops customised software for logistics. Overall, the area dedicated to the automated warehouse covers 24,000 square meters. With a height of 24 meters and a single aisle, six stacker cranes service it: half are dedicated to picking activities and the others to storage operations.

The simplified conceptual model is shown in the figure below:

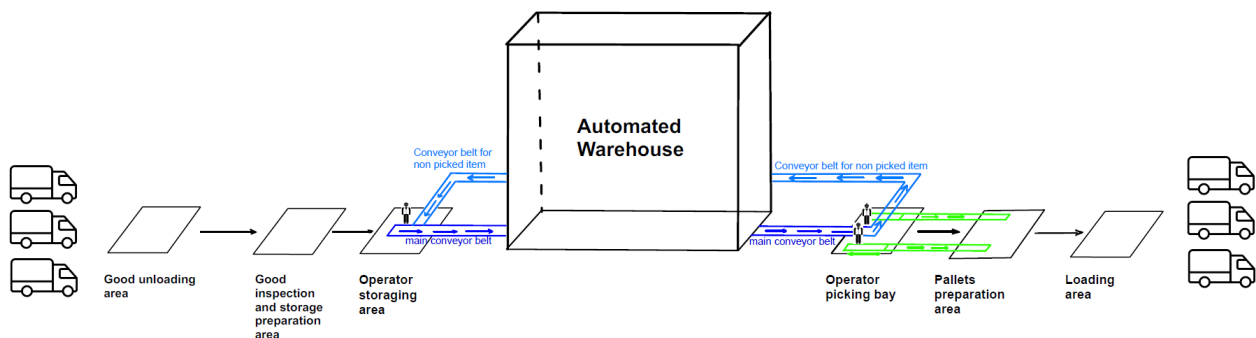


Figure 2: Warehouse Conceptual Model

When a package arrives at the warehouse, it is unloaded and inspected in the designated area. Afterwards, it is transported to the operator storage area, where the operator scans the package barcode using a handheld device and places it on the conveyor belt. The SAP software assigns the package to a specific location and subsequently stores it in the warehouse by a **AS/RS** (Automated Storage/Retrieval System).

When an order is placed, the **SAP software** organises its preparation. All the required products are initially retrieved from the automated warehouse by robots and transported via the central conveyor belt to one of the four operators' "put-to-light" picking bays. In this area, there are two operators and two other conveyor belts. On the secondary conveyor belts, there are simultaneously 15–20 different boxes, each corresponding to a customer order. When a box arrives from the main conveyor, the operator sees the number of items to be picked on a display. The employee turns around and places the items in the illuminated box; when it's done, he presses a button. Once all the orders

are completed, the secondary conveyors transport them to the pallet preparation area. Finally, if any items on the main conveyor have not been used, they return to the operator storage area via another conveyor belt, waiting to be reloaded into the warehouse.

1.2 Business Context

Dental Trey SRL operates in a sector characterised by complex logistics and high inter-dependences among the products it supplies to dental practices and related facilities. Product management is particularly challenging due to the nature of the items handled: high-value dental prostheses (e.g., titanium implants), medicines subject to stringent regulations, and items requiring cold chain logistics or cryogenic storage. The interdependence between products makes a coordinated approach essential: for instance, a dental prosthesis cannot be installed without the necessary anaesthetic, or a procedure might be delayed if complementary products do not arrive together, directly impacting the efficiency of dental professionals and the satisfaction of their patients.

Dental Trey has adopted advanced technological solutions to streamline operations and minimise potential inefficiencies despite these complexities. The SAP system, which governs warehouse management and supplier coordination, ensures optimal stock levels and automates much of the order processing, reducing errors and delays. Complementing this, the UNO platform provides a user-friendly interface for customers, allowing them to place orders online and enabling a more transparent and efficient ordering process. Operator training ensures the staff understands how to handle specific scenarios, such as managing refrigerated storage, robotic systems, cryogenic facilities, and high-value items. While the required skills are diverse, they are not highly complex and can be effectively taught through proper instruction and transparent protocols.

Dental Trey's warehouse follows a **FIFO (First In, First Out) inventory** management system to guarantee proper product rotation and maintain quality standards. The company boasts an **average product lifecycle (APL) of 22 days**, a benchmark that reflects its efficient inventory turnover and commitment to freshness. In comparison, the main competitor, AstraZeneca, with a similar **40% market share in Italy**, operates with a longer **APL of 60 days**, while smaller competitors often have shorter APLs due to limited stock sizes, which may impact their ability to meet diverse demands consistently.

Operating in a heavily regulated industry, Dental Trey ensures compliance with international standards such as ISO 9001 [11] for quality management, ISO 15001[3] for medical devices, and ISO 18001[4] for occupational health and safety. These certifications reinforce the company's commitment to operational excellence, safety, and customer trust, providing proof to stakeholders about the high standards maintained.

Dental Trey's technological demands are high, dictated by the complexity and diversity of the products managed and the ambitious performance standards the company strives to achieve. By addressing these challenges head-on, Dental Trey has positioned itself as a leader in its sector and created a sense of pride and confidence in its stakeholders, consistently setting standards for reliability, efficiency, and innovation.

1.3 Customers information

The company works in the Italian B2B dental supply market, so the main customers are:

- **Private Dental Practices** are the primary buyers of dental materials and instruments. These range from small, single-professional offices to larger clinics with multiple specialists. Their typical needs include everyday tools such as drills, mirrors, and tweezers and consumables like filling materials, anaesthetics, and polishing discs. They also invest in technological devices such as intraoral scanners, digital radiography systems, and dental lasers.
- **Dental Clinics and franchised chains** mainly operate on a larger scale, often managing multiple locations. They require significant consumable materials and advanced equipment tailored to specialised fields like orthodontics, implantology, and oral surgery. Additionally, they frequently utilise software solutions to manage patient records and schedule appointments.
- **Dental Laboratories specialise in crafting custom dental devices** such as prosthetics and orthodontic appliances. Their primary needs include materials such as resins, gypsum, and metal alloys for these products. Many labs rely on CAD/CAM technology for designing and producing items, along with ceramic furnaces, milling machines, and 3D printers.
- **Hospitals and University Dental Clinics** are focused on providing specialised care and conducting research. These institutions require high-quality dental materials and tools that meet strict healthcare standards. They also invest in advanced diagnostic equipment, such as computed tomography (CT) scanners and panoramic X-ray systems, to support clinical and research activities.
- **Training Institutions and Professional Schools**, such as dental schools and technical training centres, play a crucial role in preparing future dental professionals. Their needs include simulators, practical training materials, and advanced teaching tools. Additionally, they require essential lab equipment to support hands-on learning in student laboratories.

1.4 Suppliers' information

- **Dental Instrument and Material manufacturers produce essential tools and consumables for dental practices, including drills, mirrors**, tweezers, and materials such as resins, anaesthetics, and filling products. (e.g., Dentsply Sirona, Ivoclar Vivadent, Kerr, Septodont)
- **Dental technology and equipment providers** offer advanced equipment, such as intraoral scanners, dental lasers, digital radiography systems, and CAD/CAM tools, for precise restorations. (e.g., 3Shape, Planmeca, Straumann, Carestream Dental)
- **Manufacturers of diagnostic equipment** mainly focus on imaging tools such as CBCT systems and panoramic X-ray machines, which are essential for accurate diagnostics and treatment planning. (e.g., Vatech, Acteon, Morita, KaVo)
- **Materials for Dental Laboratories:** they provide gypsum, metal alloys, ceramics, resins,

and equipment such as ceramic furnaces and milling machines. (e.g., GC Corporation, Zirkonzahn, Amann Girrbach)

- **Suppliers of 3D Printers and Related Materials:** suppliers in this segment provide 3D printing solutions and compatible materials for producing prosthetics, surgical guides, and dental models. (e.g., Formlabs, EnvisionTEC, Carbon 3D)
- **Pharmaceutical Companies** produce pharmaceutical products used in dentistry, such as anaesthetics, antibiotics, and disinfectants. (e.g., Pfizer, Sanofi, Heraeus Kulzer)
- **Manufacturers of Dental Furniture and Chairs,** suppliers focusing on ergonomic furniture and dental chairs designed for patient comfort and practitioner efficiency. (e.g., A-dec, Anthos, Castellini)

2 Theoretical Understanding

To better understand critical incident analysis, some key definitions and models will be introduced. The first part of this section will discuss more theoretical aspects, such as the definitions; instead, the second part will be dedicated to the models used throughout the report.

2.1 Definitions

One of the main definitions used in this paper is resilience:

“The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function.”[18]

This is important because it allows us to introduce other key concepts connected to resilience. In particular, organisational resilience is composed of the different aspects that can be gathered into six categories:

- Incident management [6]
- Business Continuity [5]
- Disaster Recovery [7]
- Service Continuity [9] [7]
- Information Security [8]
- Risk Management [10]

For this analysis, the most interesting is the second, the “Business Continuity”. Business continuity encompasses organisations’ strategies and actions to ensure that essential

operations persist despite unexpected disruptions. It is a comprehensive approach beyond merely responding to disasters; it focuses on maintaining regular business functions and swiftly restoring full operational capacity. A well-structured business continuity plan outlines specific processes and procedures to mitigate risks, safeguard resources, and sustain critical activities. This proactive approach ensures that organisations can effectively navigate challenges, minimise downtime, and maintain service delivery to customers, even under adverse circumstances. Moreover, a can be defined as “the management system aimed at establishing, implementing, maintaining and continually improving Business Continuity”[5]. Inside the BCMS, there are a lot of fundamental concepts to understand better and tackle the incident with more importance reported below:

- **Business Continuity Plan (BCP)** is defined as “documented procedures that guide organisations to respond, recover, resume, and restore to a pre-defined level of operation following disruption.”[5]
- **Business Impact Analysis (BIA)** is the “process of analysing the impact over time of a disruption on the organisation” [5]

Another essential concept to point out is the categorisation of the type of impact that:

- **Financial impact:** Includes the potential revenue loss, increased operational costs, loss of future revenues, and investment losses.
- **Operational impact:** Refers to the disruption of daily business operations, affecting productivity and efficiency.
- **Safety impact:** Refers to safeguarding personnel, citizens, and related aspects.
- **Legal, Regulatory & Contractual impact:** Refers to non-compliance with legal and regulatory requirements or contractual obligations.
- **Reputational impact:** Refers to damages to the company’s reputation, which can lead to a loss of trust from stakeholders such as customers, suppliers, banks, and business partners.
- **Other impacts:** These include environmental issues, customer-related challenges, and supply chain disruptions.

Finally, in this paper, we refer to BCP as defined in “A Normative Process Model for ICT Business Continuity Plan for Disaster Events in Small, Medium, and Large Enterprises”[19] which outlines BCP as a comprehensive framework composed of structured procedures and processes designed to ensure the continuity and recovery of critical business functions during and after disruptive events. A key component of this framework is identifying essential points of failure within the organisation’s infrastructure. This involves creating detailed architectural diagrams highlighting vulnerabilities at both the software and hardware levels, ranking and testing these failure points, and incorporating only the most significant ones into the final BCP to minimise risks and ensure operational resilience.

2.2 Models

The second part of this section introduces and briefly explores several models that help structure our understanding of critical incidents and their management. These models support identifying vulnerabilities, managing risks, and developing more robust resilience strategies across various organisational dimensions. The following models— Lewis, Bow-Tie, Resilience Core Functions, Resilience Practice Bundle, and COBIT – offer a complete perspective on incident analysis, prevention, and recovery, creating a comprehensive approach to resilience and business continuity.

Lewis Model[\[17\]](#):

The Lewis Model provides a framework for analysing and positioning a company within a two-dimensional space, considering **Operational Capabilities** and **External Market Requirements**. This model is a diagnostic and strategic tool to evaluate a company's standing in response to dynamic internal and external factors.

In the event of a significant incident, the company's position within this model shifts, reflecting changes in its performance and alignment with market expectations. For instance, a decreased operational efficiency or increased market demands may alter the company's trajectory, highlighting areas needing strategic intervention to regain balance and competitiveness.

Bow-Tie Model[\[22\]](#) [\[1\]](#):

The Bow-Tie model is a risk assessment and communication tool that visualises the pathways to adverse incidents and their possible consequences. It focuses on preventing unwanted events, controlling their escalation and mitigating impacts through transparent cause-and-effect relationships. The model helps organisations prioritise interventions by pinpointing where barriers, controls, and recovery measures can be effectively integrated to reduce risk.

Resilience Core Functions[\[2\]](#):

This model comprises five functions representing an organisation's key capabilities to anticipate and adapt to after-incident conditions.

- **Sense:** Improve visibility and early detection of changes and pressures in the business environment.
- **Build:** Establish and strengthen internal capabilities proactively or through acquiring resources.
- **Reconfigure:** Adapt and reorganise structures, assets, and processes to deal with changing circumstances.
- **Re-enhance:** Recover or improve performance levels after disruptions or shocks.
- **Sustain:** Maintain operational continuity and performance to minimise long-term adverse consequences.

Resilience Practice Bundle[\[13\]](#):

It is based on categorising the resilience practices taken after and before the incident. The first dimension considered is proactivity vs reactivity: proactive actions try to prevent the disruption or its escalation, while reactive ones are done after the event to mitigate its effects. The second dimension considered is whether the practice is internal (managed autonomously by the company) or external (done with the help of partners).

COBIT 5 DSS04^[16]:

COBIT 5 is a comprehensive framework that provides governance and management guidance for enterprise IT. Within COBIT 5, DSS04—part of the “Deliver, Service, and Support” domain—focuses on ensuring that IT systems remain continuously operational and that disruptions are quickly and effectively resolved. This standard comprises eight structured steps supported by detailed activities to help maintain service availability and performance. Progress throughout the process is monitored using control objectives, which serve as benchmarks for measuring effectiveness and maturity. Furthermore, DSS04 is closely aligned with Business Continuity Planning (BCP), ensuring that IT resilience efforts are integrated with broader organisational strategies to mitigate risk, maintain critical operations, and safeguard essential business functions.

Below is a high-level overview of the typical steps involved in COBIT 5's DSS04 process. While the exact sequence or naming may vary depending on organisational context, these steps generally capture the core activities:

1. **Identify Critical Processes and Resources:** Determine which business processes, IT services, and infrastructure components are essential to operations, ensuring that continuity efforts focus on what matters most.
2. **Set Continuity Policies and Standards:** Establish guidelines, rules, and benchmarks that define how continuity will be managed, aligning them with broader organisational strategies and BCP requirements.
3. **Design Preventive and Resilient Solutions:** Implement infrastructure redundancy, failover mechanisms, and other technical safeguards to minimise the likelihood and impact of service disruptions.
4. **Develop and Document Continuity Plans:** Create detailed plans outlining the procedures, responsibilities, and resources required to maintain or restore operations during an interruption.
5. **Train and Prepare Personnel:** Ensure all relevant staff are adequately trained, understand their roles in continuity scenarios, and have the tools and knowledge necessary to respond effectively.
6. **Test and Exercise the Plans:** Conduct drills, simulations, and testing exercises to validate the effectiveness of continuity plans, identify weaknesses, and refine strategies.
7. **Manage Backups and Data Restoration Processes:** Establish reliable backup arrangements and ensure that data restoration procedures are well-documented, tested, and readily available.
8. **Monitor, Review, and Update Continuity Measures:** Continuously assess continuity performance against control objectives, incorporate lessons learned from tests

or actual incidents, and update plans and resources to reflect changing risks and requirements.

3 Methodology

The information-gathering phase began by searching for a significant operational or supply chain disruption case study. After evaluating various opportunities, we determined that the most interesting case was the automated warehouse shutdown at Dental Trey SRL. Leveraging the network of contacts, two interviews were conducted with **Klajdi Petriti, Group Treasury and Risk Officer at Dental Trey** (at the time of the incident).

The first interview, conducted online on **October 10, 2024**, lasted approximately one hour and followed a free-flowing, open-ended format, allowing the conversation to evolve naturally. This approach permitted Klajdi to speak freely, sharing his recollections of the incident and its impact on the company's operations in the subsequent weeks and months. The focus was on gaining a deeper understanding of the event, including the company's risk management strategies and resilience. The online setting provided flexibility and convenience, creating an environment where Klajdi could comfortably offer detailed insights into how the situation was managed internally and externally. At the outset of the interview, the only information available was that there had been a disruption in the automated warehouse, which had caused significant impacts on both the operations and the supply chain. However, by the end of the interview, a much clearer picture had emerged, providing a thorough understanding of the events that transpired, the nature of the problem, and the steps taken by the company to address the situation. This allowed a comprehensive overview of the entire issue, a problem with the automated warehouse in 2017, which caused the warehouse to shut down for several weeks.

The second interview, conducted in person in **Magenta (MI)** on **November 18, 2024**, lasted around an hour and a half. While maintaining a conversational tone, this interview was more structured, featuring specific, targeted questions that allowed a deeper exploration of the incident and its implications. We gained valuable insights into the company's strategies using the **Operational Resilience Survey Tool** [6]. To begin with, an in-depth analysis was conducted on the product performance requirements of the company's market. The findings highlighted the exceptional delivery speed and the ability to ensure high product quality, both critical strengths given the nature of the offerings, including medicinal products and items used in the dental and medical fields. Furthermore, a high level of product flexibility was observed, as a **wide range of options must be provided** to meet the diverse demands of this sector. Conversely, cost importance appears relatively low, as customers in this industry prioritise obtaining the specific product needed over price considerations. Regarding the current proactive practices, the analysis revealed solid internal communication and coordination among departments, although top management provided minimal employee support or motivation. Nevertheless, there are notable gaps, such as the almost complete lack of experience in handling disruptions, which, in this context, could have had a significant impact. Additionally, while operators are informed about how to react in case of incidents and are subjected to annual assessments on the actions to be taken (via tests), **no simulations** (either real or virtual) are conducted. **The company implemented a basic approach to lean practices and focus on continuous improvement.** Many processes were monitored and optimised

through SAP warehouse management software, and preventive maintenance was standard practice. The organisation regularly embraced innovation by introducing new technologies. However, gaps remained, **particularly the low level of employee cross-training programs and workers' insufficient involvement in problem-solving**. Regarding Industry 4.0, the company's adoption was limited to its automated warehouse and SAP software. Advanced technologies such as autonomous vehicles, Internet of Things (IoT) applications, and virtual or augmented reality were absent, indicating untapped potential for leveraging modern innovations.

After the interviews, extensive online research was conducted using Dental Trey's official website, Henry Schein's resources, and various articles from **Il Sole 24 Ore** to understand the incident and its broader implications better. This step was crucial for establishing a detailed context, identifying key factors contributing to the disruption, and evaluating potential strategies to enhance operational reliability and risk management practices.

4 Synthesis of Findings

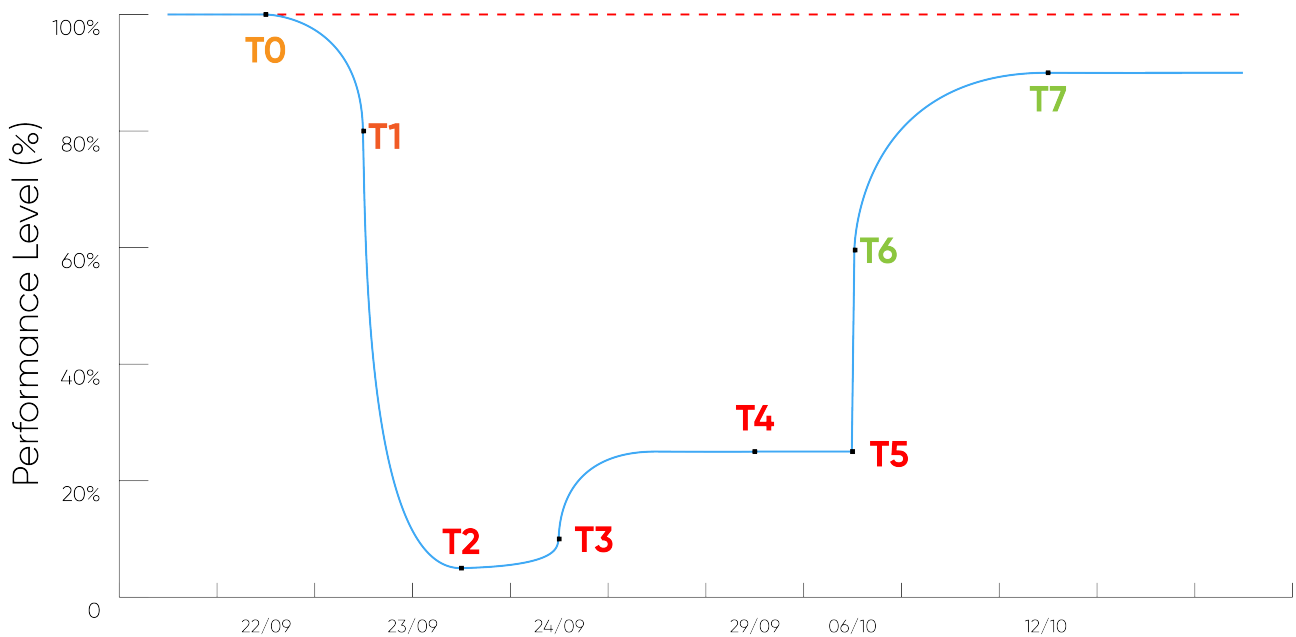


Figure 3: Timeline Analysis

Mark	Date & Time	Event
T0	22-09-2017 23:00–04:00	At night, technicians from the Japanese manufacturer remotely update the robot movement system.
T1	23-09-2017 08:00	When the warehouse opens, and the first orders are being processed, the employees in charge of the picking phase notice that the system is not working correctly.
	23-09-2017 08:00–08:30	After confirming the existence of an issue, the department head informed the warehouse manager.

Mark	Date & Time	Event
	23-09-2017 09:00–12:30	After inspecting the automated warehouse, the warehouse manager contacts the manufacturing company.
	23-09-2017 14:00–17:00	The Japanese manufacturing company remotely investigates and analyses the robots' malfunction but cannot find a solution.
T2	23-09-2017 18:00	The operators start with the manual picking from the warehouse.
T3	24-09-2017 to 26-09-2024	A regional technician dispatched by the manufacturer tries to resolve the issue, but his efforts are in vain.
T4	29-09-2017 to 05-10-2017	The manufacturing company sends technicians from Japan to Predappio, but despite a week of testing, they fail to resolve the malfunction.
T5	06-10-2017 09:00	Dental Trey turns to a private consultant who is an expert in SAP systems.
T6	06-10-2017 13:00	The expert identifies and fixes the error.
T7	12-10-2017 08:00	The automated warehouse is fully restored and resumes operations.

Table 1: Event Time Table

4.1 Incident description

On the night of **September 22, 2017**, technicians updated the software controlling the robots in an automated warehouse during routine operations. The update intended to improve the robot system's efficiency but inadvertently introduced a critical error. After the update, the robots responsible for storing and retrieving products began to misplace items, leading to significant inventory issues and delays in order processing.

The problem became evident the following morning, on **September 23, 2017**, when employees at the warehouse began processing orders. The staff working in the picking phase realised something was wrong. Despite inserting correct product codes into the system, the robots were retrieving incorrect items. Concerned, the workers immediately reported the issue to the department head, who escalated it to the warehouse manager. Throughout the morning, the warehouse manager inspected the automated system, trying to identify the cause of the malfunction. After failing to find a solution, the manager contacted the IT company that developed the robotic system to request their intervention. Later that afternoon, a technician remotely analysed the system for several hours but could not determine the reason behind the malfunction.

An emergency procedure was implemented to maintain operations while addressing the issue. The automated system was temporarily shut down, and workers manually retrieved items from storage racks, some as high as 24 meters. This time-consuming process required additional external workers to cope with the demand. However, despite their efforts, manual operations could not replicate the speed and accuracy of the robotic

system, leading to delays and inefficiencies.

A technician from the IT company's local office arrived at the warehouse in the following days. He conducted several tests, including simulations where new products were loaded and retrieved. During these simulations, the robot appeared to work correctly, giving the impression that the issue might have been resolved. However, it soon became clear that the robot's malfunction was tied to products loaded into the system **before the update. The robot's software could no longer recognise or locate these items, causing it to retrieve incorrect products.** Despite spending two days on-site, the technician could not resolve the issue and notified his managers. In response to the escalating problem, the IT company dispatched a team of specialised technicians from Japan to the warehouse. Over a week, these technicians carried out extensive testing, analysing the system's software and hardware. However, despite their expertise and efforts, they could not identify or fix the root cause of the malfunction. This prolonged downtime further strained warehouse operations and added to the financial losses.

With no solution, the warehouse management turned to an external SAP consultant, an expert in software systems. This private consultant visited the warehouse and analysed the robot's management software. Within just **four hours**, the consultant identified the root cause of the issue: a human error during the initial software update. Specifically, a technician responsible for updating the code had accidentally pressed "Ctrl+V" and the letter "b" simultaneously while pasting a code string. This introduced an unnoticed bug into the robot's system, disrupting its ability to map and retrieve previously stored products.

The consultant's quick and efficient diagnosis allowed the team to correct the error and restore the warehouse system. By **October 12, 2017**, the automated system was fully functional, and normal operations resumed.

4.2 Incident Impacts

4.2.1 Financial Impact

The financial impact of the incident was significant, primarily due to the disruption of normal operations. The inability to fulfil orders led to a sales loss estimated at **€2 million**, as customers cancelled orders or sought alternative suppliers. Additionally, to compensate for the downtime in the automated system, warehouse employees worked double shifts with a **50% pay increase** for overtime. Although this arrangement avoided hiring new staff, it temporarily increased labour costs. Lastly, the partial unloading and reloading of inventory, which involved managing approximately **200,000 product codes** with a total value of **€500 million**, added operational costs and slowed down processes. The combination of these factors resulted in significant unplanned expenditures.

4.2.2 Operational Impact

The malfunction severely disrupted warehouse operations, forcing the staff to switch to manual processes. The existing 16 employees, who usually worked across two shifts, were

required to take on double shifts to meet operational needs. Due to the high complexity of manually retrieving items from racks up to **24 meters high**, the process was slower and less accurate than the robotic system. Despite these efforts, order delays were unavoidable, and manual handling of the warehouse inventory created inefficiencies. No additional staff were hired due to time constraints and because the warehouse team was already slightly overstaffed before the incident. Nonetheless, the increased workload put significant pressure on the employees. Moreover, the malfunction created unique logistical challenges within the warehouse. The facility, spanning a **24,000-square-meter base**, is designed for robotic efficiency. Manual processes became the only option with the robots out of service, and employees struggled to meet operational demands. The warehouse's reliance on automation for handling 200,000 product codes across a single-aisle structure highlighted the vulnerability of such systems to unexpected malfunctions. Manual handling could not replicate the speed and precision of the automated system, further compounding delays and inefficiencies. And finally, when the robot was repaired, it was also necessary to reallocate all the items inside the warehouse.

4.2.3 Market Consequences

The inability to meet customer demand during the warehouse downtime led to a **5% estimated market share loss over the six months following the incident**. Although this figure was slightly inflated for insurance purposes, it reflects the temporary erosion of customer trust and loyalty. Competitors capitalised on the situation, offering more reliable services during the company's operational disruptions. The incident also damaged the company's reputation because the delivery speed went from 24 to some days or even not delivered. While the financial impact of reputational damage is difficult to quantify, it undoubtedly necessitated additional efforts in public relations and customer retention strategies to repair relationships and regain market confidence.

4.3 Summary

All the consequences discussed above are summarised in the Lewis model. (Figure 4). The model illustrates the dynamic relationship between a company's operational capabilities and external market requirements. Initially, the company was in perfect equilibrium, positioned on the fit line where its delivery speed, cost efficiency, and operational performance were fully aligned with the market's expectations and demands. This balance reflected a state of optimal efficiency and competitiveness.

However, the automated warehouse incident disrupted this harmony, moving the company to position 2. In this stage, the company experienced a sharp decline in its operational capabilities due to the failure, which caused a drastic reduction in the number of orders fulfilled. This disruption created a significant misalignment between the company's capabilities and the market's needs, leading to a loss of customer satisfaction and a weakened position in the market.

After resolving the issue with the automated warehouse, the company's operational capabilities were restored to their original level, moving it to position 3. However, the prolonged disruption had lasting consequences, as the company's market share had diminished during the period of reduced performance. This left the company with operational

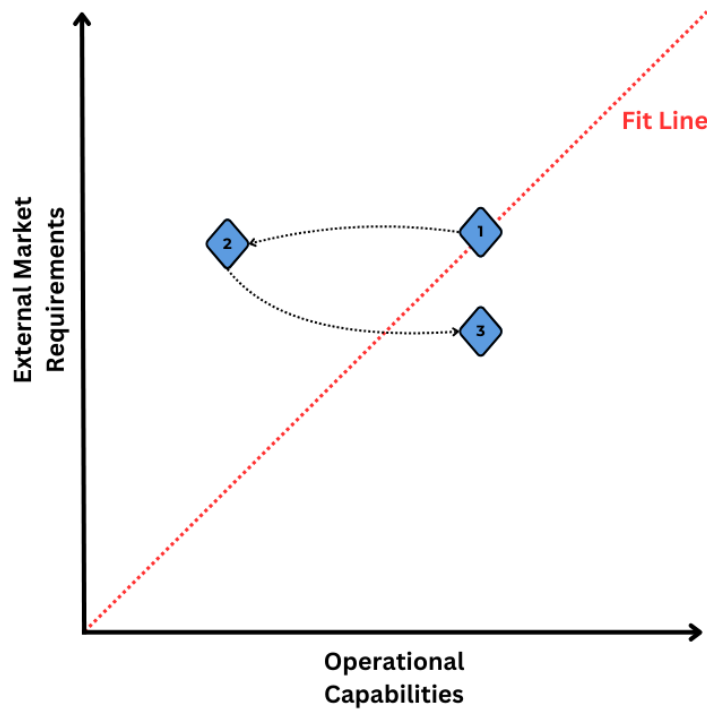


Figure 4: Lewis Model [17]

capabilities that were now oversized relative to its reduced market demand, resulting in a misalignment where resources exceeded what the market required.

At this point, the company faces a critical decision. It must choose whether to reduce its operational capacity to align with the current market size by eliminating inefficiencies or to focus on regaining its lost market share. The latter would involve investing in strategies to recover customer trust and rebuild its competitive position. This situation underscores the challenges companies face in managing the aftermath of operational disruptions, balancing internal efficiency with the need to restore external alignment and competitiveness.

5 Discussion

When the incident occurred, the company's strengths in communication, coordination, and structured organisation played a crucial role in managing the crisis. However, the absence of risk management experience in the workforce exposed significant vulnerabilities, as both employees and managers appeared unprepared, relying heavily on external assistance or instructions from higher-ups. This shows a lack of a good BCP [10] ready for an emergency like the block of the AS/RS.

5.1 Risk Management and Resilience models

Some models usually used for risk assessment offer fascinating insights. The first tool, the "Risk Matrix" shows how IT bugs should be a **medium-impact**, low-probability disruption. However, it became a **high-impact** event due to a mismanagement of the recovery part and preparation for this situation.

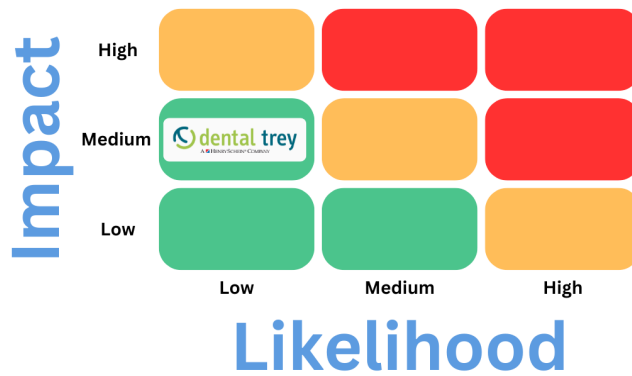


Figure 5: Risk Matrix

From the Bow-Tie model , figure 6, it is possible to see how the company had some mitigation procedures. Still, they were very generic and unrelated to the automated system, suggesting that the company wasn't ready for this kind of scenario. For example, the company transitions to manual operations for picking and storage tasks when the automated system fails, and there aren't procedures to prevent the disruption from happening.

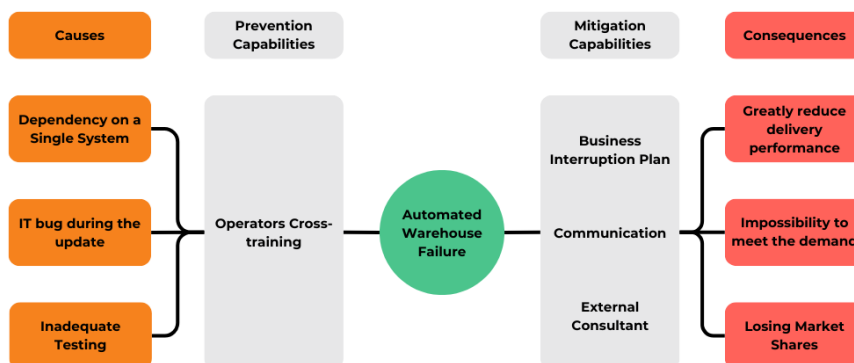


Figure 6: Bow-tie Model [1] [22]

Regarding the "Prevention Capabilities", the company has developed a business interruption plan and invested in training its operators. These training programs should ensure that all employees are fully aware of the appropriate actions to take in case of a system malfunction, fostering a culture of preparedness and quick response. However, the lack of experience with operational incidents and the absence of a comprehensive business continuity plan is a critical point that will be discussed later in the paper. This also poses a question about the quality of employee training on emergency plans.

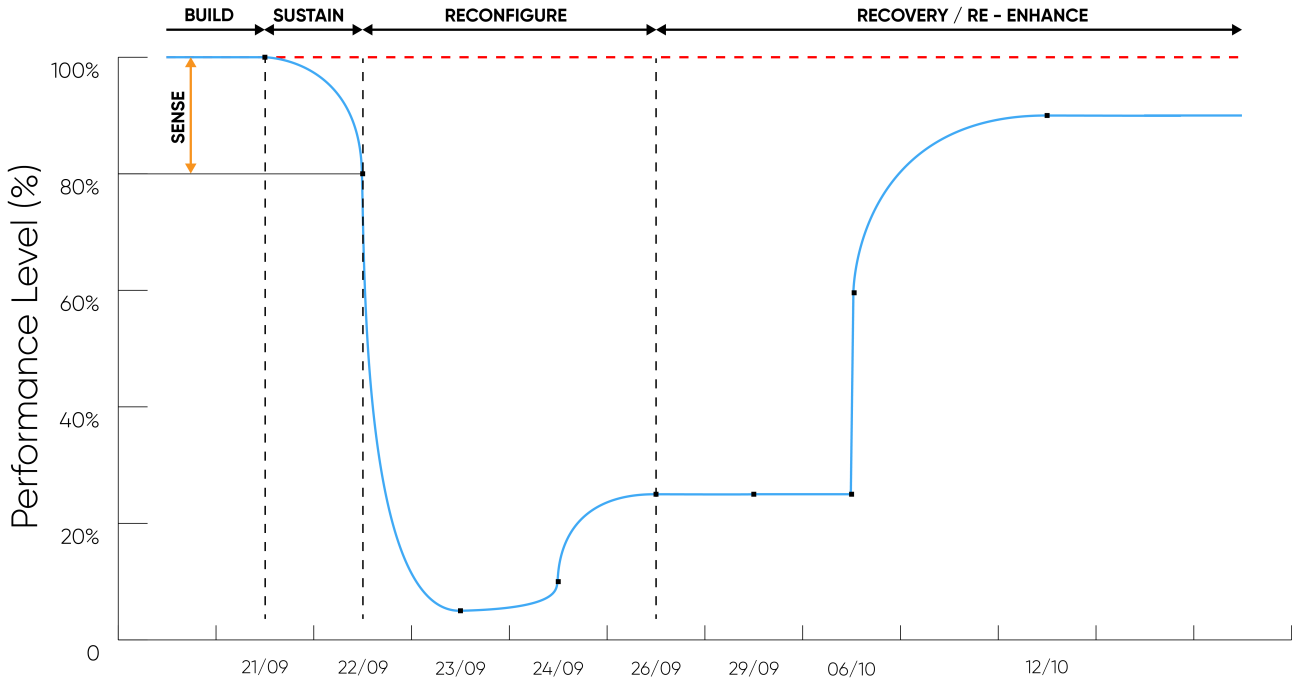


Figure 7: Resilience Core Functions Graph [2]

Category	Actions
Sense	<ul style="list-style-type: none"> • Trust relationship with suppliers (to be ready to respond to a disruption that comes from them) • Demand analysis and forecast through the SAP system • Visual inspection and diagnostics to identify potential symptoms of accidents or disruptions
Build	<ul style="list-style-type: none"> • Supplier selection process • Collaboration with suppliers to postpone the supply process • Training and testing operators about incident management procedure

Sustain	<ul style="list-style-type: none"> • Business interruption plan: Increasing the number of working shifts to maintain a certain level of operational capability • Implementing manual warehouse management to compensate for the robot shutdown (picking and retrieving activity) • Build-to-order process (to remain effective)
Reconfigure	<ul style="list-style-type: none"> • Operator duties reconfiguration • Introduction of a robot supervisor • Implementation of logistic backup, temporary transfer of operations to nearby warehouses company or external systems
Renhance	<ul style="list-style-type: none"> • Promotion and discount campaign to regain customer trust

Table 2: Resilience Core Functions

Moreover, how is possible to see from the [Table - 3 - Proactive and Reactive Strategies \[13\]](#) and [Table - 2 - Resilience Core Functions](#) the company primarily emphasises the reactive aspects of its model, with insufficient focus on proactive and resilient strategies. Consequently, an unexpected event without a reaction plan will likely result in disorganisation and confusion, leading to extended recovery times, as seen in the recent incident.

These situations can cause pretty rare issues to cause a significant distribution even if, in theory, they should have a low/medium impact on the operations. This is because the tools and practices weren't in place to prepare for this event.

	Proactive	Reactive
Internal	<ul style="list-style-type: none"> • Low Operators Cross-training • Business Interruption Plan 	<ul style="list-style-type: none"> • The organisation collects information from the incident site with its representatives. • Establish clear roles and responsibilities for recovery activities.

	Proactive	Reactive
External	<ul style="list-style-type: none"> • Trust and Collaboration With Suppliers 	<ul style="list-style-type: none"> • Relevant external actors are contacted quickly and involved. • Communicate and coordinate with supply chain actors promptly after disruptions. • Collaborate effectively with external actors to share knowledge and resources during recovery.

Table 3: Proactive and Reactive Strategies [13]

5.2 Business Continuity Plan for IT Security Management

Continuing with the analysis of the incident, another aspect to take into consideration is how was managed the cause of the problem. When it was identified that the problem was the software was the root cause of the problem, there was no backup or other type of solution in place; perhaps an external consultant's intervention was necessary to solve the issue. This indicates they lacked BCP for IT security; we can refer to COBIT 5 to better understand this.

The BCP's phases and COBIT 5 DSS04 [16] processes are linked in the following way:

The **Business Impact Analysis** is linked with DSS04.1 and DSS04.2. The company failed in the first activity, which aims to identify internal and outsourced business processes and service activities critical to enterprise operations (robot). Failing resource identification led to a lack of involvement of key stakeholders and no transparent processes with the IT company providing the automation.

The **Incident Handling** part is connected to DSS04.3, highlighting the importance of operative procedures and selecting the right people with the necessary skills. Soon after the disruption, the people involved were not the best candidates and preparing people and processes before could have had an enormous impact. It also notes that it is crucial to verify that key suppliers have a business continuity plan covering the potential disruption.

The **Risk Management** chapter covers DSS04.4, DSS04.5 and DSS0.6. The first process stresses the importance of continuous exercise and training on BCP. The company personnel knew the business interruption procedure but could not apply it, particularly in a not-considered case. The second process discusses the importance of updating the process: the company correctly puts new yearly updates. Still, it could not identify the necessity of adding a chapter on the robot (as a key resource for the automated warehouse).

The final section is **Disaster Recovery and Restoration** (DSS04.7 and DSS04.8). It highlights the importance of backups and third-party systems. Moreover, it clarifies the importance of analysing the BCP's performance after the disruption to understand its strengths and weaknesses, as seen in an iterative improvement logic.

6 Conclusion

The incident at Dental Trey SRL highlights the significant operational and financial risks that can arise from the failure of critical automated systems, even in an organisation with a strong reputation for innovation and efficiency. Despite the company's reactive practices in crisis management, the event revealed substantial gaps in **risk management, business continuity planning, and IT security frameworks**. The prolonged downtime and manual operations exposed **vulnerabilities in the company's preparedness for such disruptions**, emphasising the importance of a proactive and structured approach to operational resilience. While Dental Trey eventually resolved the issue and restored operations, the financial losses, reputational damage, and market share erosion underscore the need for robust pre-emptive measures.

To improve its resilience, Dental Trey should enhance its business continuity planning by developing a comprehensive plan that addresses potential risks specific to automated warehouse operations, including IT-related disruptions. Regular business impact analyses should be conducted to identify critical resources and processes, and scenario-based training and simulations should prepare employees for various operational disruptions. **Strengthening IT security and disaster recovery** is also crucial. This can be achieved by implementing a robust IT disaster recovery plan with backup systems for critical software updates and automated processes. Software updates should be rigorously tested in isolated environments before deployment to production systems, and regular audits should ensure compliance with IT security best practices and identify potential vulnerabilities. Improved risk management practices are needed, including using advanced risk assessment tools like the Bow-Tie Model to evaluate risks, identify preventive measures, and plan mitigation strategies. Clear protocols for engaging external consultants and vendors during incidents should be developed to ensure faster and more efficient resolution.

From the operations point of view, a carefully considered alternative could be putting a second **backup automated warehouse in place**, which could increase the overall capacity and help during disruptions. Another alternative is to find another Henry Schein partner or a **third-party company** to help handle the most urgent orders during the interruption. The second warehouse alternative could be quite costly, while the partner one could risk eroding the company market after the disruption, so both options require a dedicated cost/benefit analysis.

Finally, aligning with international standards like **ISO 22301**[5] for Business Continuity Management and **COBIT 5**[16] for IT governance will help integrate best practices into the company's strategic planning and operational processes. Dental Trey can enhance its operational resilience, minimise future disruptions, and strengthen its market position by adopting these measures. The lessons learned from this incident allow the company to evolve and become a benchmark for best practices in risk management and business continuity within the industry.

List of Figures

1	Timeline	1
2	Warehouse Conceptual Model	2
3	Timeline Analysis	10
4	Lewis Model [17]	14
5	Risk Matrix	15
6	Bow-tie Model [1] [22]	15
7	Resilience Core Functions Graph [2]	16

List of Tables

1	Event Time Table	11
2	Resilience Core Functions	17
3	Proactive and Reactive Strategies [13]	18

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Annex

The following pages report the full operational resilience survey tool compiled with Klajdi Petriti during the November 18, 2024, interview.

Operations Risk Management & Resilience Course/Module

Operational Risks and Resilience Survey

This survey instrument is developed to explore and identify operations and supply chain risk management strategies related to improving resilience of business operations and performance of manufacturing firms in the face of uncertainties that are difficult to anticipate.

The survey is divided into five sections:

- Section A: Description of the company and its business
- Section B: Performance objectives and achievements in the business
- Section C: Current proactive practices employed in the firm
- Section D: Information on a critical incident recently encountered
- Section E: Issues related to business context
- Section F: Lean Practices implementation
- Section G: Smart Manufacturing implementation

It is intended to be used along with more detail and qualitative details that you as informant shall provide to the interviewer. The interviewer will provide explanation about the questions should you require any. If you cannot answer any question, please leave it blank and go to the next one. Please kindly tell us if you remind additional details in relation to the questions while filling out this survey.

All responses will be treated with ABSOLUTE CONFIDENTIALITY. Names of companies, business units, products or individuals will not be released without prior consent from the informants.

Many thanks for your cooperation!

Section A: Description of company and business unit

If the company consists of several business units, please consider the business unit affected by the incident.

Company name:	Henry Schein Italia srl (Dental trey srl)
Interviewee's name:	Klajdi Petrity
Interviewee's job title:	Group Treasury and risk officer
Interview is conducted: (date, place, face-to-face or other means)	26-10-2024, Magenta (MI), face-to-face
Interviewee's work experience in the company (years)	7
Contact details (if you would like us to communicate reports of the study)	
Short description of main product lines/services	Dental care
Number of employees (Full-Time Equivalent)	>50
Annual turnover in Euros	46 millions
How much (%) does your main product line contribute to the overall turnover?	Don' t have a main product line , more than 40 000 products code
To which regions of the world are the main products distributed/sold?	Italy
From which regions of the world are components sourced for the main product lines?	worldwide

How would you describe the production system for your business unit's most important product line? (1) Project (2) Job shop (3) Batch, (4) Line (5) Continuous	1 and 5
Which of the following best describes the order-fulfilment practice for your business unit's most important product line? (1) Produce to forecast/deliver from stock (2) Assemble/produce to order (3) Configure/customise to order (4) Engineer-to-order	1
To what extent do you consider your company implements lean production practices? (1 =not at all, to 7=to a very high extent)	5

Section B: Performance issues

Considering the product/business unit/department that represents the majority of your business, how have the following changed over the past 2-3 years?

	Deteriorated more than 10%	Deteriorated by <10%	Stayed almost the same	Improved up to 10%	Improved 10-20%	Improved 20-30%	Improved more than 30%
1. Production first-pass quality	1	2	3	4	5	6	7
2. Percentage of defective products	1	2	3	4	5	6	7
3. Productivity (Euros of shipments per employee)	1	2	3	4	5	6	7
4. Manufacturing unit costs	1	2	3	4	5	6	7
5. Delivery speed	1	2	3	4	5	6	7
6. Delivery dependability	1	2	3	4	5	6	7
7. Dependability of after-sales service	1	2	3	4	5	6	7
8. Overall manufacturing lead time	1	2	3	4	5	6	7
9. Flexibility to changes in order volume	1	2	3	4	5	6	7
10. Flexibility to product mix changes	1	2	3	4	5	6	7

Below is a list of possible competitive priorities to win customer orders. Please indicate the relative importance of each of them to your main market.

	not important					highly important	
	1	2	3	4	5	6	7
1. Quality (superior design, conformance to customer specifications, product reliability)	1	2	3	4	5	6	7
2. Speed (delivery, shorter manufacturing and procurement lead times)	1	2	3	4	5	6	7
3. Dependability (of deliveries and after-sales service)	1	2	3	4	5	6	7
4. Flexibility (to changes in ordered product volume and mix)	1	2	3	4	5	6	7
5. Cost (manufacturing cost, employee productivity, selling price)	1	2	3	4	5	6	7

Section C: Current proactive practices

Please indicate the extent of actions/measures, described below, exercised in performing your normal operations

	very low						very high
1. Extent of communication competence in terms of precision regarding what, to whom and when to communicate	1	2	3	4	5	6	7
2. Support and encouragement from top management	1	2	3	4	5	6	7
3. Effectiveness of coordination among units in the organization	1	2	3	4	5	6	7
4. Effectiveness of collaboration with external stakeholders (e.g. suppliers, competitors, customers, regulatory bodies)	1	2	3	4	5	6	7
5. Efforts to establish processes for managing unanticipated disruptions	1	2	3	4	5	6	7
6. Initiatives to build experience and know-how of employees to manage unforeseen incidents	1	2	3	4	5	6	7
7. Experience gained from previous incidents in the company or elsewhere	1	2	3	4	5	6	7
8. Level of established suppliers relationship	1	2	3	4	5	6	7
9. Mapping of alternative supply sources in case unanticipated disruptions happen	1	2	3	4	5	6	7
10. Scanning business environment for signals of (possible) incidents that could affect the company's business	1	2	3	4	5	6	7
11. Active customer engagement	1	2	3	4	5	6	7
12. Multi-competence team problem solving approaches	1	2	3	4	5	6	7

Section D: Incident-based issues

In answering the following questions, please consider a critical incident that happened in your organization which had a significant impact on the business operations and profitability (e.g. disruptions, delay, or other form). The level of significance could depend on your interpretation.

1. What was the incident? Automated warehouse shutdown in the pharmaceutical sector
2. What was the main cause? IT bug
3. When did the incident happen (yyyy, mm, dd hh:mm)? 2017/09/22 night
4. How long did it last for having affected your performance? 3 weeks of block and 3 months to recover the performance
5. What were the immediate consequences (financial, operational, market, others)? Loss of sales (€2 million) Warehouse emptying and refilling: Loss of market share (5% loss over 6 months: slightly exaggerated for insurance purposes) Reputation damage Increased workload:

Using a scale of 1-7, please indicate your level of agreement to the statements that describe what you might have done once the critical (e.g. disruptive) incident happened.

	Strongly disagree					Strongly agree	
	1	2	3	4	5	6	7
6. The problem communicated among the relevant organization very fast			3	4	5	6	7
7. Information was collected from the incident scene by competent company representative(s)	1	2	3	4	5	6	7
8. The recovery work was executed in a structured and clear way	1	2	3	4	5	6	7
9. Clear distribution of responsibility and delegation was established during the recovery work?	1	2	3	4	5	6	7
10. Established communication competence helped us to deal with the incident better	1	2	3	4	5	6	7
11. The support and encouragement from top management during the recovery was stronger than before	1	2	3	4	5	6	7
12. The organization enhanced internal coordination to solve the problems after the incident.	1	2	3	4	5	6	7
13. The organization collaborated effectively with external actors (e.g. suppliers, competitors, customers) to manage the incident.	1	2	3	4	5	6	7
14. The employees that handled the recovery work had good experience and know-how to manage unforeseen incidents	1	2	3	4	5	6	7
15. We managed to compensate supply disruption by managing on the demand side (or vice versa)	1	2	3	4	5	6	7

Please consider operations performance for the following objectives when (just before) the incident happened.

Before the incident							Immediately after incident							After significant recovery								
low			high					Low			high					low			high			
1	2	3	4	5	6	7	16. Production first-pass quality	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	17. Percentage of defective products	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	18. Productivity (Euros of shipments per employee)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	19. Manufacturing unit costs	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	20. Delivery speed	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	21. Delivery dependability	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	22. Dependability of after-sales service	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	23. Overall manufacturing lead time	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	24. Flexibility to changes in order volume	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
1	2	3	4	5	6	7	25. Flexibility to product mix changes	1	2	3	4	5	6	7	1	2	3	4	5	6	7	

Section E: The business context

How do you rate the following complexity parameters in your business environment?

	Simple /low/					Complex /high/	
1. Product characteristics	1	2	3	4	5	6	7
2. Production process interdependences	1	2	3	4	5	6	7
3. Interaction of actors for decision making	1	2	3	4	5	6	7
4. Composition of skills and competence in the business	1	2	3	4	5	6	7
5. Organisational goals and objectives	1	2	3	4	5	6	7
6. Average product lifecycle	1	2	3	4	5	6	7
7. Diversity of inputs	1	2	3	4	5	6	7
8. Diversity and number of customer segments for major products/services	1	2	3	4	5	6	7
9. Suppliers and sub-contractors involved (number of)	1	2	3	4	5	6	7
10. Regulatory requirements	1	2	3	4	5	6	7
11. Technological requirements to meet	1	2	3	4	5	6	7

How do you rate the following parameters that describe level of unpredictability over time in your business environment?

	Low					high	
12. Rate of innovation	1	2	3	4	5	6	7
13. Internal performance requirements (technology, workforce)	1	2	3	4	5	6	7
14. Changes in customer demographics	1	2	3	4	5	6	7
15. Research and Design/development expenditure /changes	1	2	3	4	5	6	7
16. Demand predictability and stability	1	2	3	4	5	6	7
17. Suppliers' & sub-contractors' performance predictability	1	2	3	4	5	6	7
18. Predictability of competitors' actions/pressure	1	2	3	4	5	6	7
19. Changes in regulatory requirements	1	2	3	4	5	6	7

Section F: Lean practices implementation

Please rate implementation of the following practices in the organization

Description	None					Extensive	
1. We have quality management programs in place	1	2	3	4	5	6	7
2. Formal continuous improvement programs are implemented	1	2	3	4	5	6	7
3. Large number of equipment/process on the shop floor are currently under statistical process measurement and control	1	2	3	4	5	6	7
4. We use proper visual tools on the production shop floor and in other functional areas	1	2	3	4	5	6	7
5. Cellular layout and flexible manufacturing approaches are exercised in our organization	1	2	3	4	5	6	7
6. We continuously identify and remove bottlenecks from our processes	1	2	3	4	5	6	7
7. Our employees practice to reduce the time required for setting up machineries and manufacturing cycle time	1	2	3	4	5	6	7
8. We redesign and reengineering processes to improve effectiveness and efficiencies	1	2	3	4	5	6	7
9. Quick changeover techniques are implemented	1	2	3	4	5	6	7
10. We have established procedures to reduced purchase order sizes	1	2	3	4	5	6	7
11. Our order placement processes are short and clear	1	2	3	4	5	6	7
12. We have very little need for incoming material inspection	1	2	3	4	5	6	7
13. We have proper maintenance optimization techniques set up	1	2	3	4	5	6	7
14. We use preventive/predictive maintenance techniques	1	2	3	4	5	6	7
15. We acquire new process/technology to improve the availability of our production/service deliver facilities	1	2	3	4	5	6	7
16. We use job rotation, design, and enrichment so that our employees can work in a better way	1	2	3	4	5	6	7
17. Employees participate in formal cross-training programs	1	2	3	4	5	6	7
18. We have problem solving groups in which employees actively involve	1	2	3	4	5	6	7
19. We encourage flexible cross-functional work force	1	2	3	4	5	6	7
20. Our customers are actively involved in current and future product/service offerings	1	2	3	4	5	6	7
21. Our customers give us feedback on quality, delivery and other related performance	1	2	3	4	5	6	7
22. We have long term relationship with and frequently are in close contact with our suppliers	1	2	3	4	5	6	7
23. We have a formal supplier development and certification program	1	2	3	4	5	6	7
24. Our suppliers are committed to continuous improvements and cost reductions	1	2	3	4	5	6	7

Section G: Smart manufacturing implementation (Industry 4.0)

Please rate implementation of the following digital technologies in the company's operations

Description	None							Extensive
1. Advanced analytics (Data science tools for improved decision making, e.g., by gaining deeper insights, making predictions, or generating recommendations).	1	2	3	4	5	6	7	7
2. Autonomous vehicles (Solutions allowing semi- and fully autonomous transportation, ranging from long-distance to short-distance deliveries)	1	2	3	4	5	6	7	2
3. Additive manufacturing (Integrated, computer-based system manufacturing comprised of simulation, 3D visualization, analytics and collaboration tools to create product and manufacturing process)	1	2	3	4	5	6	7	
4. Internet of Things (Sensors, cameras and smart devices that process and share gathered data using internet connectivity)	1	2	3	4	5	6	7	3
5. Robotics (Physical robotic systems used across all supply chain processes within enclosed environments)	1	2	3	4	5	6	7	4
6. Virtual and augmented realities (Interactive experience where real world objects are either represented completely "virtual" or "augmented" by computer-generated perceptual information)	1	2	3	4	5	6	7	1
