Supply Chain Management and Fault Detection

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BOOKS ARCADE

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Website: www.booksarcade.co.in

Year of Publication 2023

International Standard Book Number-13: 978-81-19199-07-5

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CHAPTER 1

INTRODUCTION TO CONVEYER BELT

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In order to preserve product quality and preserve a positive reputation, all production facilities must have a mechanism for identifying and separating defective products. Therefore, we use a little conveyer belt system to illustrate such a system here.

Depending on the sort of goods, the quality may take many different forms. If a product does not fulfil its specifications, a flaw in the product is assumed to exist. Size, height, form, weight, operation, and other factors might all be at fault. The process of fault detection involves identifying the defective product and removing it from the batch so that it may either be utilised as raw material or returned to the manufacturing line for improvement. Numerous techniques, including batch testing, one-by-one testing, and manual product testing throughout production, may be used to find faults. All of these techniques take a lot of time and need labour [1].

With the use of a fan and ducts to remove dust and small particles from woodworking processes, pneumatic conveying was invented in 1866. Since then, the use of pneumatic conveying in the chemical, cement, agricultural, pharmaceutical, and food processing sectors has significantly increased. It now encompasses practically all fine granular bulk materials. Unfortunately, pneumatic conveying is still very much an empirical technique, which may result in several incorrect applications. Numerous colleges throughout the globe are currently doing research, but the theoretical answers to "two-phase flow" are sometimes too complicated for the average engineer to understand. Additionally, a lot of these solutions need for empirically obtained coefficients, which are not always accessible [2].

Conveyor belt scales are crucial to the production of a wide range of pre-packaged goods. The main goal of this project is to improve the accuracy and speed of the industry's measurement of material dimensions, and to accept or reject material in accordance with predetermined standards based on scalar and pneumatic system. Because every enterprise needs an automated dimension measurement and control equipment to approve or reject the project as per standard height, these traditional techniques are not appropriate for industrial applications. The suggested architecture of manufacturing lines solves this issue. Introduction: As automation levels rise, automated control technology is increasingly employed in the manufacture of quantitative packaging, including that for the packing of food, fertiliser, and oil bottles. These issues are currently being solved through automation systems. Results from our design are effective and fruitful [3].

One crucial feature of the system is the autonomous nature of the mechanism, which enables uneven products to be automatically detected and rejected by a different mechanism that pushes them away from the belt. When a larger box moves off the conveyor belt, this device linked to the main structure may detect it and cause the conveyor belt to halt for a bit so that the box can be removed. We may use two different sized tiny carton boxes for the demonstration. Conveyor belt systems come in a broad variety and are used for many purposes.

The baggage of passengers may be scanned by the airport conveyor system to look for metal items like guns, gold, etc. The majority of conveyor belt systems used for mining operations in open areas are designed to transport material over large distances; in these locations, very long conveyor belt systems, ranging in length from a few hundred metres to kilometres, will be in use. Conveyor belts of many shapes and sizes are used in industries, and some of these systems may transport material up to a particular height thanks to ramp-style conveyor mechanical structures. This mechanism for a conveyor belt is designed with industrial applications in mind [4].

The production of soap depends on the precise weight of the soap. Industries must have top-notch machinery and trained labour, but doing so would raise the price of the product and risk the demise of the firm or manufacturing sector. To address this issue, quality departments have been established in every industry to monitor product weight. In the proposed system, packaged products like soap move along a conveyor belt mechanism with the help of a sensor and load cell. The sensor is used to detect the product, and the load cell is programmed so that only products that meet the required weight requirement—in this case, 70 grams—are permitted for further packaging. Products that do not meet the requirement are automatically rejected by a separator arm and motor [5].

Because raw materials and energy are costly, the ceramic tile sector has high manufacturing costs. Industrial software for automated visual inspection is suggested to categorise the quality of the finished product in order to lessen the negative effects of these expenditures. The final tile in the manufacturing line's quality may be directly impacted by a wide range of factors. In other words, a process failure that results in an asymmetrical geometric composition in the tile structure might happen early on.

Because of this, the last stage of the production process mandates that tiles be put through a quality operation with the intention of finding any flaws. In various businesses, the quality of the tiles is often checked visually, which has a tendency to classify them incorrectly. As a result, the employee's experience, judgement, level of weariness, and visual ability are crucial for successfully identifying failures.

Four distinct types of flaws relating to the various RGB colour components are often introduced into the product throughout the tile creation process. The first class refers to spots that have an impact on the green and blue colour components, the second class has an impact on the red and blue colour components, the third class has an impact on the red and green colour components, and the fourth class has an impact on all three colour components. The fifth class is finally defined as tiles with no failures [6].

Finding product flaws plays a crucial part in preserving the product's quality, making it one of the biggest difficulties. Any modification, no matter how little, to the product's size or form may alter its configuration and cause it to malfunction. A computer or other controller manages the process in automated manufacturing. On the assembly line, the entire product is created, packaged, and kept. As our application in this case, the lock is discussed.

It is hard to see an issue on the manufacturing line since everything is automated. Because of this, a lock may be poorly made and incapable of locking a door or the facility where it is intended to be utilised. When a lock's key is fitted with a different key during mass manufacturing, the lock sometimes stops working.

Since of this, if the product doesn't function when it is delivered to the client, it may need to be replaced, which takes time because two locks need different keys, which means that all locks must be manually tested.

Occasionally, a key is manufactured with an incorrect cut that tends to not function properly, which prevents the lock from working.

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CHAPTER 2

COMPONENTS OF FAULTY PRODUCT DETECTION AND SEPARATION SYSTEM

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Finding product flaws is one of the most difficult tasks because doing so is essential to maintaining the product's quality. Any alteration, no matter how slight, to the product's size or form has the potential to change how it functions. In automated manufacturing, the process is controlled by a computer or another controller. The entire product is created, packaged, and stored on the assembly line. Here, the application is covered. Given that everything on the production line is automated, it is hard to see a problem. As a result, it's conceivable for the process to go wrong and the thing you make to be faulty. This results in the product malfunctioning when it is given to the customer, necessitating replacement, which necessitates testing each product on humans and takes time since two comparable things must be switched [1].

When designing software, there is often a logical gap between the description of the requirements and the specification of the product. This is often when the process of transforming unstructured, intelligible requirements into a formal system design starts. The development of safety-critical technology is likewise subject to the same flaw in the process. Safety rules are laws that deal with system security. If a system doesn't have any negative consequences on its users or its surroundings, it is considered to be safe. It is the duty of the system design to make sure that any errors that do happen when the system is in use do not have catastrophic results. However, it's possible that safety standards were already breached while the system was being developed. The gap between the requirements definition and the software design specification is one of the significant locations where system safety may be jeopardised by the introduction of design faults [2].

The belt conveyor

The conveyor belt, which consists of two cylindrical rollers driven by a DC motor that also serves as a pulley, is used to hold a continuous loop of oil bottles that need to be measured. The conveyor belt rotates across cylindrical rollers, one of which is powered by a DC motor, while it moves the goods on it forward. The conveyor's DC motor is powered and signalled at this place via the electrical circuit [3].

Conveyor Pulley

A conveyor pulley is a mechanical tool used to tension, change, and drive a conveyor belt. A pulley, which may be an idler or a driving pulley, is located at the discharge end of a conveyor belt. The shells of contemporary pulleys are rolled, and they have flexible end discs and locking systems. Systems with larger diameter pulleys are often lag-fitted in order to increase traction and pulley life. The end of the belt conveyor may have a driving pulley or an idler pulley, which is the opposite of the typical discharge end [4].

Pneumatic Cylinder

In pneumatic systems, compressed air is utilised to store energy in a potential state. A pneumatic system is created when compressed air is let to expand, fusing kinetic energy and pressure. To do any reasonable amount of work, a system that can fill an air tank with enough air at the proper pressure is needed.

Solenoid Valve

An electromechanical solenoid valve is a controlled valve. A solenoid, an electrical coil with a movable ferromagnetic core in its centre, is built within the valve. Core is referred to as a plunger. The plunger closes a small aperture while it is in the rest position. The coil's ability to conduct electricity results in the creation of a magnetic field. The plunger is subject to a force from the magnetic field. The plunger is pushed in that direction, toward the centre of the coil, causing the orifice to open. Using this basic concept, solenoid valves are opened and closed. The word "solenoid" is often used when a coil is used to create a magnetic field around a magnetic object or core. A solenoid describes the technique through which a transducer transforms energy in motion. The majority of the time, solenoid valves control air flow as switches and are activated by the solenoid. If the solenoid is operating, the valve opens (current is applied). if the pneumatic cylinder controls the movement of the pneumatic solenoid [5].

Microcontroller

The first and most crucial consideration when selecting a microcontroller is its efficiency and cost-effectiveness in carrying out the necessary tasks. When evaluating the need for a microcontroller-based project, an 8-bit, 16-bit, or 32-bit microcontroller must be capable of handling the computing needs of the task in the most efficient manner.

The Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins, 15 of which may be used as PWM outputs, 16 analogue inputs, 4 hardware serial ports, a 16 MHz crystal oscillator, a USB port, a power connection, an ICSP header, and a reset button. A 16 MHz crystal oscillator and a USB port are also included. It already has all the components needed to support the microcontroller; all you need to do to get going is put in a USB cable, an AC-to-DC converter, or a battery. With the Mega 2560 board, the majority of Uno-specific shields function [6].

The Arduino Mega may be powered by either an external power supply or a USB connection. It selects the power source on its own. For external (non-USB) devices, power may come from a battery or an AC-to-DC converter (wall wart). The adapter must be connected by inserting a 2.1mm center-positive connection into the board's power port. Battery leads may be inserted into the Ground and V in pin headers of the POWER connector. The board may operate on an external source with a voltage range of 6 to 20 volts. However, if the 5V pin receives less than 5V or less than 7V, the board might become unstable. If more than 12V is utilised, the voltage regulator might get overheated and become damaged. The recommended voltage range is 7 to 12 volts. The Mega2560 is different from all previous boards in that it does not make use of the FTDI USB-to-serial driver chip. Instead, it features an Atmega8U2 with a USB to serial converter written into it.

Proximity sensor

Even when an object is not physically touching the proximity sensor, it may still be able to detect it. A proximity sensor often emits an electromagnetic field or beam of radiation, such as infrared, coupled with a return signal that is subsequently checked for changes. The entity that is being sensed is sometimes referred to as the "proximity sensor's target." Different sensors are required because proximity sensors have a variety of targets. While a plastic target may be compatible with a photoelectric or capacitive proximity sensor, an inductive proximity sensor requires a metal target at all times. Because there are no moving parts and no direct physical contact between the sensor and the object being detected, proximity sensors are very reliable and have a long working life. Additionally, proximity sensors are utilised in machine vibration monitoring to detect changes in the distance between a shaft and its supporting bearing. A proximity sensor with a relatively narrow range is often used to create touch switches.

Typically, there is a logical disconnect between the requirements definition and the software design specification throughout the software development process. Informal, understandable requirements must generally be converted into a formal system design at this stage. This gap in the development chain for safety standards also applies to the development of safety-critical systems. System safety is the subject of requirements referred to as "safety requirements." The lack of catastrophic effects on the system's users and surroundings is what is meant by a system being safe. The architecture of the system must ensure that any faults that do occur during system operation do not have catastrophic effects. However, safety criteria may already have been violated during system development: one of the critical areas where system safety may be compromised by the introduction of design flaws is the gap between requirements specification and software design specification.

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CHAPTER 3

COMPONENTS OF FAULTY PRODUCT DETECTION

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An electrical device that produces infrared light in order to detect certain features of its environment is known as an infrared sensor. An IR sensor can monitor an object's heat while also seeing movement. Instead of generating radiation, these sensors solely monitor infrared radiation. These radiations may be detected by an infrared sensor even if they are undetectable to human vision [1].

An IR LED (Light Emitting Diode) serves as the emitter, and an IR photodiode, which is sensitive to IR light of the same wavelength as that produced by the IR LED, serves as the detector. When IR light strikes the photodiode, the output voltages and resistances adjust according to the intensity of the IR light received.

The two sets of LEDS on the IR sensor are utilised to detect obstacles. The IR Transmitter and IR Receiver are the two sets of LEDS. When no obstruction or item is in its path, the light that was sent by the transmitter vanishes after travelling a certain distance. The receiver LED detects the transmitted light when it is reflected off of an item or impediment within the range. We may test the object's size or shape—in this example, the padlock—thanks to such a phenomena [2].

One may determine the form and size of an item by positioning the necessary number of IR sensors in the appropriate location and orientation.

Arduino Board: An open-source microcontroller known as an Arduino may be quickly and simply programmed, erased, and reprogrammed at any moment. The Arduino platform, which was first introduced in 2005, was created to provide professionals, students, and amateurs a simple and affordable method to build gadgets that use sensors and actuators to interact with their surroundings. It is an open-source computer platform used for building and programming electrical devices, based on basic microcontroller boards. It may also function as a minicomputer, exactly like other microcontrollers, by accepting inputs and using different Arduino shields to receive and transmit data over the internet.

Pneumatic Actuator

A pneumatic actuator generates motive force primarily via the use of a piston or a diaphragm. It maintains the air in the top part of the cylinder, enabling air pressure to drive the piston or diaphragm to turn the valve control element or move the valve stem. A pneumatic actuator is used as a separator in this system, and it is set to only expand when a defective product is discovered. The actuator's extended rod strikes the component and aids in removing it from the packing line [3].

Any rotating electrical equipment that transforms direct current electrical energy into mechanical energy is referred to as a DC motor. The majority of kinds depend on the magnetic field's forces. For a portion of the motor's current to sometimes shift direction, almost all kinds of DC motors contain an internal mechanism that is either electromechanical or electronic. Since they could be supplied by existing direct-current lighting power distribution networks, DC motors were the first kind that was often utilised. A DC motor's speed may be varied across a large range by varying the supply voltage or the amount of current flowing through its field windings.

A fastener is a mechanism that mechanically connects or fastens two or more things. Fasteners are often used to construct non-permanent couplings, or joints that may be taken apart without harming the parts they are connecting. Permanent connections may be made, for instance, by welding.

Stainless steel, carbon steel, and alloy steel are the typical materials used to make steel fasteners.

Shafts/Axle

An axle is the centre shaft for a wheel or gear that rotates. Axles on wheeled vehicles may either be fastened to the wheels and rotate alongside them or fixed to the vehicle and rotate around the wheels. In the first scenario, the mounting locations where the axle is supported have bearings or bushings. In the latter scenario, a bushing or bearing is positioned within the wheel's centre hole to permit rotation around the axle. The latter form of axle is sometimes referred to as a spindle, particularly when used on bicycles.

Belts and Pulleys

A belt is a flexible material loop that is used to mechanically connect two or more spinning shafts, most often in parallel. Belts may be used to measure relative movement, convey power effectively, or create motion. The shafts do not have to be parallel; belts may be looped over pulleys with a twist in between. In a two-pulley system, the belt has two options: it may be crossed such that the driven shaft's direction is reversed, or it can drive the pulleys normally in one direction (if on parallel shafts) (the opposite direction to the driver if on parallel shafts) [4].

Components and pneumatic cylinders

Engineering that uses gas or pressured air is known as pneumatics. Compressed air or compressed inert gases are often employed as the power source for pneumatic systems in industry. Cylinders, air motors, and other pneumatic equipment are driven by a centrally placed and electrically powered compressor. When choosing between pneumatic systems and electric motors and actuators, solenoid valves are used to operate them either manually or automatically.

Bearing housing

As we are all aware, in order to achieve any frictionless rotational motion, bearings must be installed on the shaft, and in order to secure the bearing in the machine, bearing housings are required. Depending on the need, numerous kinds and sizes of bearing housings may be produced. Any material that is appropriate for the machine and the environment where it will be utilised may be used to make it [5].

Coupling and Spacers

A coupling is an electrically powered device that joins two shafts at their ends in order to convey power. Normal couplings prevent the separation of shafts while they are in use, however certain couplings have torque limits that may be exceeded and cause them to slide or detach. A spacer is a cylindrical piece of metal with threading that is used to provide distance between two parallel pieces [6].

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CHAPTER-4

MODELS OF FAULT DETECTION SYSTEM

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In many operations management automation systems, fault detection and diagnostics is a crucial element.Problems are sometimes known as "faults." A "root cause" flaw is a basic, unaddressed issue that may result in additional issues and noticeable symptoms. (It can be imperceptible to the naked eye.) Additionally, methods for repair are often linked to a primary problem.The term "fault" or "trouble" need not refer to a particular piece of hardware or even to a total breakdown of a piece of equipment. An off-spec product or a non-optimal procedure, for example, might be considered problems. In a processing plant, hardware failures may be the primary cause of suboptimal performance, but other factors such as poor operating targets, subpar feedstock quality, poorly tuned controllers, a partial loss of catalyst activity, a buildup of coke, low steam system pressure, incorrect sensor calibration, and human error are also possible contributors. A flaw may be seen as a binary variable ("OK" vs. "failed") or it might have a numerical "extent," such as the volume of a leak or a measurement of inefficiency [1].

A witnessed event or changing value is referred to as a symptom and is necessary to identify and locate defects. When actively testing a system rather than just passively monitoring it, a symptom is referred to be a test or test result if it is the outcome of an inquiry or an on-demand data request.

Even if you are unaware of the underlying reason, fault detection involves detecting that a problem has arisen. Different quantitative or qualitative methods may be used to find faults. The multivariable, model-based strategies that will be covered later fall within this category. Statistical Process Control (SPC) measurements, summary alerts produced by packaged subsystems, and basic, conventional procedures for single variables are also included. Alarms based on high, low, or deviation limits for process variables or rates of change are another example of this.

Finding the source of an issue, whether one or several, so that a solution may be implemented is known as fault diagnostics. When distinguishing it from fault detection, this is often referred to as "fault isolation." "Fault isolation" highlights the difference because "problem diagnosis" in common, informal usage often incorporates fault detection [2].

The corresponding system and user interfaces, as well as workflow (procedural) support for the whole process, are other Operations Management Automation components that are connected to diagnosis. Notifications, online directions, escalation processes if issues are ignored, fault mitigation activities (what to do while waiting for repairs), direct remedial actions, and steps to return to normal when repairs are finished are workflow phases that may be human or automated.

Automated problem diagnosis and identification mainly rely on sensor data or performance metrics. In many applications, including those in the process industries, sensor failures are among the most frequent equipment failures. Recognizing sensor flaws as well as process concerns must thus be a top priority in those businesses. In many applications, it is quite difficult to tell the difference between sensor difficulties and process problems. Instruments used to monitor process variables such as flow, level, pressure, temperature, and power are included in our definition of "sensors." Other metrics, such as error rates, CPU usage, queue lengths, lost calls, etc., may be included in other categories, such as network & systems management[3].

In the information that follows, we primarily concentrate on online monitoring systems, which may also include some human input from end users like plant operators but are mostly dependent on sensor or other automated inputs. But we also take into account a larger perspective of diagnosis, one that includes the business process of fault management in addition to merely seeing it as a technology. The management of big, complex processes, such as those found in the process industries and network & systems management, often uses diagnosis as a decision support activity rather than a completely automated operation. Additionally, because a lot of diagnosis is done in settings like customer service contact centres, it is a perfect match for such operations. In some circumstances, a workflow engine as well as the standard problem detection and diagnostic tools may be available to provide assistance.

Fault isolation and detection may be done in a variety of ways. The majority of real applications incorporate numerous methodologies since each has advantages and disadvantages. In this section, we outline a few of the key aspects that set the various strategies apart from one another[4].

Model based reasoning

The usage of explicit models and the kind of models utilised is one of the key differences between various fault detection and diagnostic methodologies. "Model based reasoning" is the term used to describe the process of using models of the observable system as a foundation for defect identification and diagnosis.

Causal models

The use of causal models is a significant particular instance of model-based reasoning. Causal models record cause-and-effect data.

In actuality, there are delays or lags between causes and effects in physical systems known as causality. This is necessary because mass or energy must overcome resistance caused by inertia, thermal inertia, inductance, or other physical phenomena in order to move.

Pattern recognition, classifiers, and fault signatures

A generic method called pattern recognition compares an issue's reported symptoms to a list of known symptoms for every potential condition in an effort to find the best match. For each identified defect, we may express the "pattern" or "fault signature" as a vector (1-dimensional array) of symptoms.

Neural networks

A collection of input/output data is used to create neural networks, which are nonlinear, multivariable models. They could be used to spot patterns and occurrences as event detectors. Additionally, they may be utilised as diagnostic models in model-based reasoning or as classifications directly for identifying defect signals. Workflow and procedural techniques that mimic the decision-making process rather than the observable system

By developing processes for forming judgements based on the observed data, some defect identification and diagnosis is handled. Instead of modelling the system being diagnosed, the decision-making process is directly modelled here.

Event-based fault correlation, diagnosis, and identification

An event is a change in a monitored object's state. Events include things like alarms. Diagnostics that include occurrences can vary greatly from those that involve a predetermined set of variables.

Comparing active testing and passive system monitoring

Many diagnostic procedures for online monitoring systems presumptively scan every variable of relevance on a regular basis. However, it is often desirable to request non-routine testing. Testing serves as the basis for diagnosis for maintenance reasons.

Implementations and techniques based on rules

In the majority of situations, rule-based systems just apply the aforementioned methods, acting more as a programme control mechanism than a distinct diagnostic method.

Hybrid strategies

A model is not necessary for pattern recognition on its own. On models, though, the input for building the signatures for the recognized errors may well be based; for instance, as residuals from models of normal behaviour. Models that are static or dynamic may both use this generic strategy.

For dynamic models, the patterns may be established, for instance, on the comparison of anticipated measurement values with actual measurement values in a Kalman filter. In addition to various methods for fault isolation, Smartsignal provides products based on an empirical process model of typical operation utilised for fault identification. It is also possible to integrate models of anomalous behaviour with pattern recognition. For instance, modelling for the SMARTS InCharge product used a qualitative cause-and-effect model of anomalous behaviour known as a fault propagation model. However, as part of the creation process, this model was then utilised to automatically create fault signatures, which are a kind of compiled knowledge. The basis for diagnosis at runtime was comparing the observed data to the closest fault signature. As a result, the product at runtime exhibited the traits of a pattern matching solution[5].

Sometimes a qualitative model is truly just present in the application developer's mind. Based on their understanding, they immediately create the signatures. As a result, the overall technique often combines pattern recognition with a model-based approach. Many different methods of defect detection and diagnosis may be supported by certain programmes, like GDA, which also supports upfront filtering and event production[6].

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CHAPTER 5

MODEL BASED REASONING FOR FAULT DETECTION AND FAULT DIAGNOSIS

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One of the significant distinctions between strategies for fault detection and diagnosis is whether explicit models are employed, as well as the kind of models used. The process of locating and diagnosing errors using models of the observable system is known as "model-based reasoning." The process of designing the application entails a significant amount of model definition after that. A "engine" combines model knowledge with observable data to make decisions at runtime. The Ishikawa "Fishbone" diagram used in statistical quality control is an illustration of a qualitative model (SQC). Even though the diagnosis is often performed manually as the diagram is being created, these diagrams may (and should) be documented and later used online in an automated system[1].

The usage of models provides a number of advantages, such as:

Since models are application-independent, they may be used to foresee the impact of flaws as well as to detect issues.

Since the development process is standardised, it is often easier to analyse and reuse software with fewer faults for several instances of the same equipment.

Limitations and presumptions will probably be more apparent

Particularly for first principles models, they are more likely to reflect physical norms than observable coincidences that might only apply under certain conditions.

Model-based reasoning may take many different shapes. The models might be used to represent both normal and abnormal processes. They might be compiled against "first principles," causal or non-causal, probabilistic vs deterministic, and so forth. They might be qualitative (for instance, based on cause/effect theories) or quantitative (based on data and formulae). These variations are then detailed[2].

As representations of typical behaviour for systems with numerical variables, engineering models such as algebraic equations or differential equations may be used. Neural networks may be used to approximate functions and represent typical behaviour. State transition diagrams are one of several models that explain how things usually work. Then, part of the defect detection process involves examining whether these models are being applied to the observed sensor data. For instance, when the model is a state transition diagram, certain steps must be taken or the mathematical model's equations must be followed within a given tolerance [3].

Models of usual operation are quite helpful in identifying flaws. Model deviations, commonly referred to as "model residuals," may be sensitive problem detectors since mistakes imply that the models' underlying assumptions are no longer true. If the model is substantially thorough, the majority of critical defects will result in some noticeable deviation. The possible flaws don't even have to be known about or predicted for this detection to work. One drawback, which is especially troublesome for quantitative models, is that the models of normal functioning could only be relevant to a certain set of operating conditions and operating modes. Models become less accurate when operating conditions change, which raises model residuals and may show problems that are not really present. A "false positive" has occurred [4].

In certain situations, fault detection is sufficient. This is the case when the equipment that has to be replaced when it breaks down right away matches the model of normal functioning. Fault isolation doesn't need to go any farther than what is necessary to identify the replacement component. Another example is when a single operator is in control of a large system, and the biggest obstacle is just getting them to notice the problem since, once they do, they know what to do.

However, the bulk of circumstances call for further investigation. Since the model's typical functioning does not take into account the relationships between faults and model residuals, additional information must be used to isolate faults and determine their root causes. A pattern-matching method or a causal model of aberrant behaviour are often used to achieve this.

Developing and maintaining engineering models of normal behaviour may be challenging and costly. One possibility is to develop models of abnormal behaviour. These are often qualitative and only need to capture the more significant behavioural changes caused by failures rather than the smaller, predicted variations. For instance, fault propagation models characterise the effects of defects by modelling cause and effect. Each influence has the ability to multiply and result in additional effects. These causal hypotheses eventually link overt signs of problems to their underlying causes. Predictions about the effects of a root cause problem are therefore feasible. Diagnostics, on the other hand, can reverse this approach and put more emphasis on the symptoms before possible causes [4].

Sometimes the effects of certain faults are included in models of normal operation, combining aspects of models for both normal and abnormal operation. For instance, when utilising state transition diagrams, this makes sense. In quantitative models, faults often have an estimated extent. Examples include sensor bias, leaks, heat exchanger fouling as indicated by the heat transfer coefficients, and more. In general, this is not recommended. It may be possible to incorporate too many degrees of freedom, which makes it simpler to "blame" reported data deviations from the standard model. The information provided by the model and sensor input is often insufficient to determine the magnitude of many faults. It is sometimes very difficult to precisely predict the effects of probable defects using models of typical processes since there are frequently just too many of them. This system is also vulnerable to unmodeled faults since, in order to account for discrepancies, it would assign model vs. observed value errors to the modelled problems. This approach is shown using a Kalman filter with a very basic model in Estimation of Flows and Temperatures in Process Networks [5].

A good hybrid approach is to use residuals from quantitative models of normal operation as inputs to a qualitative model of abnormal operation. A conventional quantitative material balance that identifies material loss or the presence of an unexpected component might be one input for a qualitative fault model where a leak is an identified fault. Similar to this, a fault model that specifies fouling—a deposit of insulating material that prevents heat transmission might take as an input lower heat transfer than predicted by a heat exchanger model.A similar approach is to use estimate techniques like data reconciliation for algebraic models or Kalman filters for dynamic models. Use the deviations between the expected and actual measurement values—referred to as the "innovation" in Kalman filtering terminology—as inputs for pattern matching, training using data acquired from known failures, or through simulation. Rather to only examining the model residuals, the estimating step is necessary. Examples of these methods when used with algebraic models are given in "Neural Nets for Fault Diagnosis Based on Model Errors or Data Reconciliation" [6].

Static vs dynamic models

Dynamic models explicitly depict behaviour across time, while static models do not. This separates numerical models based on algebraic models from those based on differential equations or difference equations. Dynamics may be a part of qualitative models as well. For example, time delays may be included into cause-and-effect models. State transition diagrams, often known as Petri nets, are a kind of dynamic model that show how states change over time and are influenced by external events. Frequency response analysis is unusual in fault detection, with the exception of event creation, although it does provide a way to algebraically characterise certain dynamic behaviour.

Timing errors may often arise when the system is not based on a comprehensive dynamic model, or even when a dynamic model is not entirely accurate (which it never is). By synchronising inputs, static models may help explain temporal delays, as discussed in the section on causal models (whether qualitative or quantitative). This is one way to transform static models into dynamic ones. The delays and lags included in the synchronisation incorporate a piece of a dynamic model, even if the dynamics are just approximations based on real data. Similar to how steady state models are often used in process control to determine process improvements before being widened to incorporate temporal lags and delays.

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CHAPTER 6

ISSUES IN EVALUATING TECHNIQUES

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All solutions that are implemented as software will have issues with user interfaces for end users and app developers, systems engineering, serviceability, building generic libraries describing constantly repeated components, ease of modification for maintenance, computing speed and storage requirements, and so on. But finding faults and diagnosing them come with certain special problems[1].

Multiple faults against the single fault assumption in actual use. There are often a number of open issues in big, sophisticated operations (such as refinery control centres or network management centres). Numerous diagnostic methods are hampered by this. In large-scale applications like process monitoring and network management, fault isolation solutions based on a single-fault assumption would be practically worthless if not for some of the partial workarounds presented below.

Robustness: balancing sensitivity against false positives

There is always some "tuning" involved in fault identification and diagnosis. It is possible to tailor a system to be particularly good at seeing or identifying certain issues. However, it also has a tendency to indicate issues when none really exist. Sensitivity and false alarms must be balanced. This is an extension of the issue with establishing straightforward alarm levels. Problems will be discovered early on if alarm threshold limits are too near to regular operations. False alarms will thus be caused by slight transitory variations[2].

Filtering: Noise is virtually always a problem for sensor-based systems. The main goal of filtering is to minimise noise by combining several values of variables that have been sampled throughout time in order to cancel out at least part of the noise. Please refer to the section below this one for a discussion on how to lessen the effect of high frequency noise and "spikes" for single variables:

Filtering: Robustness when there are faults in the sensors or the model is a key factor to take into account when assessing diagnostic approaches. A system will be sensitive to mistakes in an input if it fully accepts it as a symptom or test input. Similar to this, any system that blindly trusts its own models would be vulnerable to inaccuracies in those models. Conflicting facts and false conclusions may be the outcome in any scenario. The inaccuracies might be more significant than merely momentary timing issues.

The majority of diagnostic systems approximate in certain ways, including locating the "nearest" problem signature, while also acknowledging that there will always be mistakes. This may also be seen from the perspective that most systems incorporate evidence. When inputs are in dispute, some kind of weighted average will be used[3].

Scalable event-oriented design for huge systems

Complex matrix computations are necessary for many model-based methods. Large systems struggle to scale with this. One strategy is to simply divide the complex diagnostic system into a number of smaller, independent ones. Because of this, diagnostic systems may not take into consideration all potential interactions in a complex system. However, this could not be a big issue if there are enough sensors.

Focusing on unusual occurrences and reasoning about the events rather than all the underlying data at once is another essential technique for large-scale systems. Raw data, such temperature measurements, are converted into events, like high temperature alarms, in a separate stage called event production. Events may also be produced using SPC (Statistical Process Control) computations. Events might also be generated based on calculations made using intricate models of typical functioning, alerting researchers to data that deviates from anticipated behaviour. The generation of events for use in models of aberrant behaviour may therefore be done by using models of normal behaviour. This combines the sensitivity of typical models for issue identification with the ability of models of atypical operations to isolate faults.[4]

Events like straightforward alarms have long been created in the process industries. In recent years, alarm management systems have also examined the effects of alarm combinations. The roles of "managers" who generally processed and correlated the events and "agents" who typically created events were developed and standardised in the context of network management. Every piece of machinery has an agent. Each agent primarily keeps track of the histories of the numerical data required to produce events locally. The management processes' "event correlation" is a byproduct that includes fault diagnostics. Added degrees of hierarchy led to "manager of managers" systems. All of this was an effort to address a variety of issues and occurrences. The section on Integrity/Optegrity event-oriented technology provides descriptions of several examples of these systems. SMARTS InCharge, a network management tool, is another instance of an event-oriented system (This was bought by EMC and incorporated into their products.).

Only few diagnostic approaches call for event creation. Information is lost when data, which is often numerical, is reduced to clear occurrences that are either present or not. The compromise is often made to manage bigger systems since simply dealing with events leads to easier diagnostic computations.Any (hardware) sensor will malfunction eventually. When a sensor fails, its value must be considered as unknown until it is fixed. Wire failures, power outages, or network issues may also cause sensor readings to become unknown. This must be handled gracefully by the fault detection and diagnostic system, which must provide the best outcomes. Furthermore, it must avoid assuming anything by default. For instance, when the sensor value used to trigger the high temperature event is unknown, it should not be assumed that the absence of the event means the temperature is okay. Previous estimates of fault probability may be helpful in the absence of more data, but prior estimates of sensor readings may result in erroneous inferences[5].

Modeling suppositions and "new defects"

It is challenging to predict or even consider every potential fault situation. Novel faults are errors that occur that were not anticipated during the creation of the application.

Knowledge visibility and explanation tools

Like most people, plant operators and their management despise "black boxes" that tell them what to do but cannot explain why. A user should be able to determine the rationale for a certain decision's timing in the ideal system (either in announcing a fault or the recovery from a fault).

Visibility of all the system-built knowledge is a related problem. Users need to have faith that all known fault scenarios are covered and that no inherent flaws exist that might result in incorrect inferences. People may officially examine knowledge if it is clear and apparent in some way, rather than having to wait for errors to occur during runtime. Such assessments by individuals with diverse experiences are crucial if the functioning of the diagnostic system is safety-critical[6].

Systems built on fault propagation models, logic trees, or procedural approaches like decision trees in a graphical language may provide clear explanations and transparency of the information they hold. (The implementation will determine whether they do or not, but the capability is there.) This transparency may also be achieved using pattern matching techniques based on the explicit listing of fault signatures; anybody can see the defects and their accompanying symptoms as described in the fault signature. However, as the number of defects and symptoms increases, fault signature matrices become huge and difficult to comprehend. The signatures may be more modular and simple to comprehend if an underpinning model, such a fault propagation model, is employed to build them.Engineering equation-based methods are less convincing, but they may be accepted since their underlying assumptions, limits, and assumptions may at least be stated. The weakest approaches in terms of explanation and knowledge visibility are those based on black box methods, such statistics or neural net classifiers.In embedded systems, transparency for explanation may not even be a concern while making a diagnosis, and there may not even be a direct human user. But even for embedded diagnostic systems, model information openness might be crucial for conducting efficient evaluations.

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CHAPTER 7

PROJECT IMPLEMENTATION FOR FAULT DETECTION AND DIAGNOSIS

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Projects that implement fault detection and diagnosis are comparable to other monitoring-related projects, including process control or IT system management. Depending on the organisation, development procedures that are already in place as standards, and contractual agreements, several project implementation approaches are used. Instead of tackling a project entirely at once, it is preferable to divide it into many short development cycles[1]. This will allow you to gain expertise and valuable outcomes more quickly. An "agile" technique has several advantages, to use the language of software engineers. For internal development projects, this functions well. However, this could not always be practicable, as in the case of a fixed-price agreement by an outside vendor that only permitted a few encounters with the customers. Even then, the job may often be completed in a number of smaller phases [2].

In general, prototyping has a lot of advantages. It aids in requirement clarification and instructs both users and application developers. It may inspire ideas, momentum, and enthusiasm.

Once the fundamental system architecture, integration, and diagnostic framework has been established, each short cycle of development may, for instance, address the following top N root causes problems and the following top N observed symptoms, or it may concentrate on a particular area of a plant or a specific category of equipment. N might be 10 when scheduling updates at a set price or much less for incremental internal work [3].

The following stages are often carried out throughout a development cycle.

Specifications for use (requirements and high-level architecture & design)

At this point in the project, typical problems are:

- Determine the system under observation.
- Determine the objectives of the diagnostic system.
- Determine who all system users are (end users like plant operators and managers, engineers, application developers, application maintainers, systems support, etc., and their needs for GUI and access.)
- Determine other system "actors" (such as additional software) in order to determine data availability, testing requirements, and system integration requirements.
- Determine the "experts": the informational sources, including engineers, operators, etc. They will provide and/or evaluate models and heuristics.
- Decide which models or heuristics are accessible[4].
- Define potential root causes that have to be investigated, beginning with the most crucial ones such those that have a significant effect (safety, cost, etc.) and those that happen often.

- Define some of the primary symptoms that have been seen, beginning with the most significant ones, such as those that relate to issues that have a large effect (safety, expense, etc.), or those that happen often.

Establish the strategy for measuring the effectiveness of the application.

High-level definition of GUI requirements

Determine the system's limitations (e.g., required hardware & software by corporate standards)b Using reviews to prototype (optional, but always a good idea if possible to do).Define the architecture, hardware, and high level design once there are approximations of the system's long-term scope[5].

Cost projections

Review, approval, and documenting of specifications precise planning and execution

At this point in the project, typical problems are:

- An intricate GUI design
- Find any parameters, such as event thresholds and model parameters, that have not yet been established (including any necessary plant tests or expert interviews)
- Any necessary models, pattern definitions, processes, etc., should be built.
- Complete any required system integration "bridges"
- All more computer code must be finished.
- Metrics are precisely designed and implemented[6].

Test Plan

Review, approval, and recording of the design

Remote testing and evaluation

At this point in the project, typical problems are:

- Create a testing environment
- Utilizing simulated values as necessary, carry out the test strategy in the testing environment.
- Examining and approving
- monitoring of objects discovered during testing
- local testing and evaluation

At this point in the project, typical problems are:

- installation of a system with live data
- Intensively monitored testing by application developers
- tune-ups and repairs as necessary
- formal system evaluation and approval
- monitoring of objects discovered during testingappointing and training

At this point in the project, typical problems are:

End-user training

- Run the system online under the supervision of the application developers
- tune-ups and repairs as necessary

- Adopt metrics for evaluating application success
- Educate system maintainers, if they are distinct from application developers
- provide the operating and maintenance manuals
- Trial phase with call-in assistance
- regular maintenance and system operation

The project's current cycle is over, and the system is now the end user's property.

At this point, common problems are often addressed.

Tune as necessary

- modifications as necessary to accommodate adjustments to the facility or its operations
- Identification and bug reporting
- looking for signs of issues in operations and analytics
- Make note of potential new applications

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CHAPTER 8

INTRODUCTION TO SUPPLY CHAIN

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The supply chain, a network of businesses, people, activities, information, and resources, is used to deliver goods or provide services to customers. In the course of supply chain activities, raw materials, natural resources, and component parts are turned into finished commodities that are subsequently sent to the end customer. If there is recyclable residual value in a complicated supply chain system, used products may re-enter the network at any point. Supply chains assemble value networks. Suppliers in a supply chain are sometimes grouped by "tier," with first-tier suppliers supplying products directly to consumers, second-tier suppliers supplying products to the first tier, and so on [1].

A typical supply chain begins with the environmental, biotechnological, and political regulation of environmental assets, is followed by human resource extraction, and includes multiple production links (such as component construction, assembly, and merging) before actually moving on to multiple layers of storage facilities of ever-decreasing sizes and increasingly remote geographic areas, and finally finding the customer. Only as a consequence of customer behaviour at that stage of the supply chain do raw materials and finished items arrive.

Many of the transactions that take place in the supply chain are between different companies that aim to maximise their profits in their respective sectors but may know little to nothing about or care about the other supply chain players. The term "chain" and the ostensibly linear structure it denotes have come under fire for being "harder to relate to the way supply networks really operate," and have since been replaced by the phrase "extended enterprise," which refers to the loosely coupled, self-organizing network of businesses that work together to offer goods and services. A chain is basically a very complex and dynamic network of supply and demand [2].

If every important business has access to all relevant information, then every firm in the supply chain has the chance to contribute to the optimization of the whole supply chain rather than sub-optimizing based on local optimization. The end outcome will be better overall production planning (Figure 1).

Figure 1: Components of supply chain.

By successfully integrating SCM, competitors will now compete on the global market on the basis of supply chains rather than companies. By using all resources, including labour, inventory, and distribution capacity, as efficiently as possible, SCM's major objective is to meet customer expectations. In theory, a supply chain should balance supply and demand while using the least amount of inventory possible. One part of supply chain optimization is working with suppliers to eliminate bottlenecks. Using site allocation, vehicle routing analysis, dynamic programming, and traditional methods are some more considerations. Strategic sourcing to balance the lowest material cost and transportation is another. Just-in-time production techniques are used [3].

The term "logistics" refers to activities involving product distribution within a single company or organisation, whereas "supply chain" also includes manufacturing and procurement and, as a result, has a much broader focus because it entails multiple companies (such as suppliers, manufacturers, and retailers) working together to meet a customer's need for a good or service. Many companies choose to work with a third-party logistics provider to outsource the logistical aspect of supply-chain management starting in the 1990s (3PL). Businesses utilise contract manufacturers to outsource their production. IT organisations have stepped forward to help manage these complex networks. Cloud-based SCM solutions are at the vanguard of next-generation supply chains because of their impact on the optimization of time, resources, and inventory visibility. Cloud technologies, which allow work to be processed via a mobile app even when there is no internet connection or coverage, answer the common issue of inventory situated in places without such services [4].

The COVID-19 outbreak caused supply chains and shipping to slow down globally in 2021, which resulted in shortages everywhere and altered customer behaviour. In addition to needs and constraints affecting workforce numbers, the COVID-19 epidemic among workers was a factor in the economic slump. Items from the cargo shipping sector were left at the port since there weren't enough staff.

Particularly in the automotive and electronics sectors, the supply chain problem has been made worse by the associated global chip shortage. The long-term effects of the supply chain concerns are escalating the 2022 food crisis and other pandemic-related food security issues. Early in 2020, the COVID-19 pandemic started to hinder the global supply chain as businesses paused production until safety precautions were put in place. Despite the hopeful expectations made by businesses for the next year, global trade continued to decline and did not fully recover. New challenges like the Delta variation and the limited availability of the COVID-19 immunisation in developing countries slowed the recovery of global production in 2021, even as the economies of wealthier, immunised regions, such the United States and Europe, resumed their spending patterns. For instance, Vietnam is a major supplier of apparel to the United States. The country was able to control the pandemic in 2020 thanks to a strict lockdown system, but outbreaks in 2021 forced the closure of major enterprises, in part because the workforce was still mostly unvaccinated. In order to sustain production in 2021, the Vietnamese government ordered that personnel in higher-risk locations remain on-site [5].

Economists pointed to lean manufacturing, sometimes known as "just-in-time" production, as the main reason for the supply chain disturbance. Lean manufacturing reduces the amount of inventory held in warehouses and reduces overhead costs by carefully matching the intake of raw materials and the output of finished products from manufacturing facilities. It is especially sensitive to rapid changes in demand since it relies on very accurate demand forecasting to offer the cost reductions and economies of scale that are its main benefits. When the COVID-19 epidemic began to close down manufacturing units, the several enterprises that had incorporated lean principles in their production pipeline were affected.

These same facilities later failed to keep up with the increased demand for consumer goods and medical supplies like personal protective equipment (PPE), leading to large backlogs. Due to these disruptions, ports like the Port of Los Angeles, a crucial route for imports from Asia, have been unable to immediately clear their shipyards, which has made the supply chain problem worse. It has been argued that stockpiles and supplier diversification should get more focus as a consequence [6].

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CHAPTER 9

SUPPLY-CHAIN SUSTAINABILITY

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Supply-chain sustainability is the contribution a company's supply chain may make to the advancement of human rights, ethical employment standards, environmental improvement, and anti-corruption principles. Supply-chain management must increasingly include sustainable options. How businesses conduct themselves is changing as awareness for sustainability grows. Whether driven by their consumers, company beliefs, or commercial opportunity, conventional considerations like quality, efficiency, and cost constantly fight for attention with concerns like working conditions and environmental effect. A sustainable supply chain seizes value chain possibilities and grants early adopters and process innovators considerable competitive advantages [1].

The vital connections that link the inputs and outputs of a business are supply chains. Reduced prices, just-in-time deliveries, and shorter transit durations have all been traditional difficulties that needed to be overcome in order to effectively respond to business concerns. Supply chain sustainability is now being considered by many firms as a new yardstick for effective logistics management due to the rising environmental, social, and economic consequences of these networks and increasing customer demand for eco-friendly goods. This change may be seen in the realisation that successful supply networks are sustainable supply chains [2]. Many businesses are only able to evaluate their own company operations' sustainability; they are unable to include their suppliers' and clients' needs in this assessment. Because of this, estimating their actual environmental and societal costs is quite difficult. The concept of supply chain sustainability has advanced significantly, and benchmarking tools are now accessible, making it possible to create and carry out sustainability action plans.

By concentrating their supply chain sustainability efforts on the environment, supply chain executives may produce outcomes in the short term. In order to create a supply chain that is more environmentally friendly, consider the following four areas:

Shipping: It's critical to provide customers the information and tools they need to make eco-friendly choices, since consumers reward companies that embrace sustainability. Do they absolutely need that order the next day, or would three to five days be adequate? Do they require each item as quickly as feasible, or can they wait until all of the goods in an order are ready before receiving them all at once? With a "green" shipping option at checkout, you may highlight the trade-offs. Similar research and solutions may be offered to their B2B clients by suppliers of transportation and third-party logistics [3].

Positioning your inventory to best fulfil each request requires visibility throughout your whole network. Furthermore, you may place goods on purpose closer to the user to provide the best of both worlds: quicker availability and reduced emissions.

Packaging: Modify your assortment of product packaging to match evolving purchasing trends. Cheaper packaging is not as necessary when there is less foot activity in retailers. You may be able to reduce the number of costly displays and shop-in-store anti-tampering measures. Include many goods in one box to avoid waste and expenses as online purchases and pickup or ship from store options become increasingly common.

Returns: Remarketing returned goods as soon as possible will reduce waste and safeguard the bottom line. By doing this, $309 billion in value of returned items to merchants and the significant number of returned goods that go to landfills each year in the U.S. alone are reduced.

Opportunities for a sustainable supply chain over the long run:

The phrase "plan, manufacture, and deliver" is used often in supply chain discussions. Focusing on product planning and the factors you can alter over time for a more sustainable supply chain is crucial as supply chain professionals establish longer-term objectives [4].

Materials: Look for chances to employ recycled materials in the production of goods, like Patagonia does, or follow Parker Hannifin's example and refrain from utilising environmentally hazardous materials. Innovations like the biodegradable plastic substitute from Newlight Technologies open up new, environmentally friendly possibilities.

Create your own sustainable and viable ecosystem of partners, suppliers. Develop organisational and governing structures that are consistent with common principles, like The North Face's Futurelight line of clothing and Farmer Connect for the coffee trade. Reevaluate packaging with a focus on reducing the quantity and kind of trash and improving the simplicity with which it may be recycled. A notable example is Nespresso, which sends recycling bags with shipments of coffee pods.

Circular models: Reduce the negative effects of items on the environment and increase the amount of materials that are reused by reselling returns, such as the Eileen Fisher Renew take-back programme. Additionally, items like Plastic Bank may be repaired or serviced as part of a lifetime guarantee, while products like Coach can have parts reused, the complete product recycled, or both fresh revenue models Investigate leasing or "product-as-a-service" models for everything from recreational equipment like REI provides to office furniture, lighting, and special occasion clothing.

Optimum methods for sustainable supply chains

Businesses are under pressure to improve the sustainability of their supply chains since doing so has genuine financial advantages. The best practises you use will assist you in creating a strategy that identifies important players, defines short- and long-term objectives, creates a timeframe, allots financing, incorporates intelligent workflows and digital solutions to change operations, and tracks progress. It's also critical to understand that a "sustainable" supply chain isn't always the same as a "responsible" one. A responsible supply chain normally makes sure that it adheres to all ethical and regulatory standards. However, this does not support sustainability. Environmental and social benchmarks are taken into consideration in a sustainable supply chain. Every link in the chain must take into account how its operations might benefit society and the environment in the long run[5].

The route to sustainability cannot be taken in a single day, and it cannot be reached via ineffective or uncaring efforts. To assist the required cultural and procedural changes, it could also be essential to make an initial investment. Starting today and building on each minor success will encourage creativity throughout the process, strengthening the commercial case to support the social argument. Environmental issues are now a topic of debate for companies all around the world due to shifting rules and consumer expectations. The only real option for any company's long-term success will be a sustainable approach to supply chains [6].

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CHAPTER 10

SUPPLY CHAIN VARIABLES THAT IMPACT SUSTAINABILITY

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Depending on the quantity and placement of intermediary facilities in the supply chain, the supply structure may change. The supply chain typically consists of the following facilities: suppliers, manufacturers, distributors, wholesalers, and retailers. Each facility in the supply chain processes orders based on the information at their disposal and sends them to the plant directly upstream[1].

The upstream facility supplies the downstream plant's demand from available stock. Upstream facilities point in the direction of the end provider, whereas downstream facilities point in the direction of the final consumer. Customers pick up the goods from the final supply chain site in the end.A sustainable supply chain is advantageous for both company and the environment. However, too few businesses are reaping the benefits of sustainable supply chains. Numerous studies have shown that although many supply chains may operate in accordance with sustainability standards, many of them are not genuinely sustainable; in one analysis of 40,000 CSR reports, just 5% quantified the company's environmental effect. Sustainability in the supply chain offers businesses financial savings, improved client connections, and environmental advantages. However, achieving these objectives calls both scientifically sound objectives and commercially sensible measurements. To achieve verifiable, long-term success, your supply chain must include these three sustainability factors.

Three responsibilities social, environmental, and financial are needed for supply chains to be sustainable. These three components will sound familiar to those of you who are acquainted with the Triple Bottom Line (TBL) accounting technique. TBL accounting assesses a firm's total performance rather than only concentrating on profit and loss by calculating the influence the organisation has on:

These three criteria may also be used to gauge sustainability in supply networks, just as it is for whole corporations. As a consequence, a lot of forward-thinking businesses are now exploring methods to tie their procurement strategy into their broader sustainability plan. A procurement technique that supports sustainability at every stage—while also saving you money is produced when people, planet, and profit are used as the three main pillars of your supply chain strategy [2].

How? Understanding your influence on both your workforce and the areas in which you operate is made easier when you keep an eye on the people. Energy efficiency gains and a variety of logistical optimizations result from an understanding of the environmental effect your supply chain has. Increasing revenues also entails expanding your company's financial worth and reducing expenses. Let's now take a look at how procurement experts may identify ways that these components can enhance the overall sustainability of the supply chain and the operation as a whole.

Environment: Supply networks must become more resilient as a result of the additional risks posed by climate change. Businesses are establishing carbon footprint goals, and 65% to 95%

of their overall emissions come from their suppliers' activities. It is clear that these environmental effects are having an effect on businesses in many sectors of the economy. For instance, food and beverage firms are especially sensitive to the effects of climate change since shifting weather patterns may interfere with agricultural output. They can react to problems and improve supply chains by measuring supply chain resilience on variables including the availability of natural resources, infrastructure, financial resources, and social safety networks, among others [3].

Society: In addition to ensuring sustainability and resilience, an ethical supply chain is essential to uphold a supplier code of conduct and assure corporate social responsibility. Employees should be treated with respect at work, and fundamental human rights must not be violated. Companies like Nike and Apple, for example, have come under scrutiny for the working conditions and salaries of its employees since they outsource the production of their goods to nations like China. In supply chains where unsettling societal breakdowns occur, such as with and for internationally traded products, consumers are demanding more openness and traceability. In several sectors, forced labour, which is defined as work done under duress or unwillingly, is a problem that is often hidden upstream in the supply chain from potential buyers, consumers, and end users.

Companies need to set quantifiable objectives for increasing their beneficial social effect if they want to increase social sustainability. Consider the suppliers as an example. Working with suppliers that uphold ethical labour standards and adhere to health and safety requirements is essential for sustainable supply chain management. Additionally, it entails ensuring that they don't contaminate and interfere with the communities in which they operate. Making sure your vendor rotation includes a variety of vendors can help you create a more fair company by ensuring your supply chain is sustainable. The company's good deeds at one point in the supply chain help your customers all the way up. According to one research, Millennials are willing to pay extra for items from businesses that match their beliefs and put a priority on corporate social responsibility.

Government: Along with social and environmental considerations, governance practises in global supply networks might endanger the sustainability of such systems. Governance elements include rules and regulations for nations and businesses. The aim of a firm, the function and make-up of the board of directors, shareholder rights, and the methods used to evaluate corporate performance are some of the proper governance practises that buyers check in their supply chains [4].

Buyers have a lot of influence on suppliers' and vendors' business practises thanks to their buying power. Businesses that play the role of purchasers get products or services via organisational processes like buying, procurement, or sourcing, usually for use or consumption inside their own company. The next link in the supply chain is often where suppliers or vendors sell their products or services. Thus, buyers may only interact with the top layer of their suppliers while the supply chain upstream is made up of several complicated supplier tiers.

Companies that assist suppliers in developing and implementing sustainability programmes that directly advance their own objectives have achieved progress in the field of sustainable buying. Buyers are attempting to meet sustainability objectives by establishing performance requirements for their suppliers and evaluating sustainability performance similarly to other commercial issues like cost, quality, and timeliness. Collaboration is a crucial component of effective sustainable supply chains.

Collaboration is uncommon because many businesses worry about losing commercial control when working with others [5]. One example of this is the practise of sharing distribution, which prevents the sending out of half-empty vehicles and ensures that deliveries to the same address are made on the same truck. Companies may significantly lower the cost and environmental effect of their delivery by investing in alternate forms of transportation like the usage of airships and canals [6].

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CHAPTER 11

GAS-TURBINE ENGINES

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Gas-turbine engines are any internal combustion machines that turn a turbine using gas as their working fluid. In particular, the term is frequently used to apply to a whole internal combustion engine, which comprises a turbine, a compressor, and a combustion chamber.

The propelling force or useful work that can be accomplished by a gas turbine engine. When powering a pump, propeller, generator, or other mechanical device, a pure jet aircraft engine may also generate thrust by speeding up the turbine exhaust flow via a nozzle. Compared to a revolving internal combustion engine for the same output, this type of engine could produce a lot of power while also being lighter and smaller. The up-and-down motion of a piston is the basis for reciprocating engines; this movement must be converted to rotational motion by means of a crankshaft arrangement. An instantaneous spinning shaft is powered by a gas turbine, in contrast. Even though the gas-turbine engine is a conceptually simple technology, the extreme temperatures and stresses it undergoes during operation need careful design and costly materials to be employed in its component fabrication. Because of this, the construction of gas-turbine engines is often limited to large units where it is financially feasible [1].

Primary components Gas turbine engine

Compressor

The original gas turbines employed centrifugal compressors because they are easy to operate and inexpensive. These compressors are less efficient than the conventional axial-flow ones and are limited to low pressure ratios. Due to this, centrifugal compressors are currently mostly used in small industrial units. An axial-flow compressor is the counterpart of a reaction turbine. The channels for the blades, that mimic twisted, highly curved air foils, must provide a tangential force to the liquid with pressures becoming larger on one of the blade's sides than on the other. During subsonic flow, an increase in pressure forces an increase in flow area, which reduces the flow velocity between both the blade channels and diffuses the flow. The array of compressor must be seen as a group of air foil shapes due to their close closeness and high curvature. Pressure will rise not just along the blade but also throughout the spaces between them. Loss in a real unit are brought on by leakage, secondary circulation, flow resistance, wake created by blade sets before it, and swirl flows. For cascades, that are fixed blade assemblies, this cannot be accomplished since actual blade arrangements in a rotating assembly must be verified using specialised test settings or rigs.

Along with having the right aerodynamic shape, blades must also be manufactured to be lightweight and resistant to harmful vibrations. Recent breakthroughs in the design of compressor (and turbine) blades are made possible by extensive computer programmes. Only very small pressure increases may be controlled by a compressor stage, which typically has pressure ratios per stage of 1.35 or 1.4 to 1 in a modern design. However, a reaction-turbine stage may be able to achieve rather substantial expansion-pressure proportions. Therefore, compression devices need more steps than turbines. A compressor will "stall" if higher stage pressure ratios are used, which will cause turbulence, a slower pressure rise, and a loss of engine power. Additionally, the flow has a tendency to separate from the blades. Unfortunately, compressors work best when they are not in this so-called surge condition, where even little disturbances may lead to problems. In order to keep efficiency high without delaying the compressor, the designer struggles constantly [2].

As compressed air is released, its volume decreases. Due to this, if the through-flow velocity is to be kept almost unchanged, the circular passage area should also decrease, which requires the blade to shrink at system pressure. To keep a proper balance of blade-tip velocities and airflow velocities, the front, low-pressure end of the compressor must often revolve at a slightly slower pace than the rear, high-pressure end. This is done in large aircraft gas turbines by utilising "spooled" shafts, where the low-pressure end shaft, driven by the low-pressure component of the turbine, travels at a different speed inside the hollow high-pressure compressor/turbine shaft, with each shaft possessing its very own bearings. There have been developed both twin-spool and triple-spool engines [3].

Burning Chamber

The air leaving the compressor must be first decelerated before dividing into two streams. When the smaller stream is supplied centrally, atomized fuel is introduced and burned in a region in which a flame is held steady by a turbulence-producing barrier. The greater, cooler streams would then be introduced into the chamber through apertures along a "combustion liner," which is a form of shell, to drop the temperature to a level suitable for the turbine intake. Depending on the design of the engine, combustion may occur in a single circular tube with fuel injection nozzles positioned at various points around the circumference or it may occur in a series of almost cylindrical parts known as cans that are spaced apart from one another around the engine's circle [4]. The issue of producing almost uniform exit-temperature distributions in a short aircraft combustion chamber may be lessened in stationary applications by longer chambers with partly internal reversed flow.

Turbine

In order to expand the hot gases through up to as eight stages, the turbines are frequently constructed using the reaction concept and one or two spooled turbines. Typically, a high-pressure turbines that only drives the compressor performs part of the expansions in a turbine powering an external load, while a separate, "free" turbine connected to the load does the remaining expansion.

Engines for high-performance aircraft sometimes use many spools. An outer spool that spins at 9,860 revolutions per minute is powered by two high-pressure turbine stages, while an inner spool that rotates at 3,600 revolutions per minute is powered by four low-pressure turbine stages, which also power the bypass air fan and four more low-pressure compressor stages. With a 30.5:1 total pressure ratio, this concept is used in a large aviation engine. In permanent installations, the typical number of turbine stages is three to five. Due to high centrifugal blade stresses and temperatures at the turbine intake, the use of specialised metallic alloys for the turbine blades is necessary. A single crystal of such an alloy may sometimes form. It is also necessary to cool very hot blades using colder air that is drawn directly from the compressor and fed via internal channels. Presently, two methods are used [5]:

(1) jet impingement on the inside of hollow blades, and

(2) air escaping through tiny holes to provide a cool blanket over the exterior of the blades.

Start-up and Command

Regardless of the amount of electricity needed, a gas turbine engine driving an electric generator has to run at a consistent speed. A reduction in load from the design limit may be compensated by using less fuel while keeping the engine running at the same speed. Reduced fuel flow lowers the combustion chamber's exit temperature and, therefore, the amount of enthral drop that the turbine can use. This little decline in turbine efficiency has no impact on the compressor, which continues to handle the same amount of air. The aforementioned method of control differs significantly from a steam turbine, which must alter its mass flow rate to account for changing loads. Gas turbine engines in aircraft are more difficult to control. The required power and, thus, engine speed, may need to alter in response to changes in altitude and aircraft speed. The mass flow rate through the engine is reduced at higher altitudes due to lower air-intake temperatures and pressures. The fuel flow and engine speed in modern aeroplanes are controlled by sophisticated computer-driven systems that continuously monitor all crucial parameters [6].

For stationary applications, a small diesel engine may be used as the start-up external motor for gas turbines instead of an electric one.

As soon as its complexity was recognised, the gas turbine engine was disassembled into 9 distinct components.

1. Rotor
2. Fan
3. A low-pressure compressor.
4. An exhaust from a turbine casing
5. Reduced Pressure Turbine High-Pressure Turbine
6. Diffuser High-Pressure Compressor
7. Retire

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CHAPTER 12

VENDOR/SUPPLIER SELECTION

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A vendor, often known as a seller, is an organisation that offers products or services to a supply chain. A supply chain vendor often produces inventory or stock products and sells them to the chain's next link. These phrases now describe a provider of any products or services. Anyone who offers products or services to another business is referred to as a vendor or supplier in the context of supply chains. Vendors may engage in business-to-business (B2B) or direct-to-consumer (B2C) or business-to-government (B2G) sales (business to government). While some vendors produce goods that may be stored and then sold to clients, other vendors provide services or experiences. Both the terms vendor and supplier are often used interchangeably. The distinction is that suppliers give the products or services, while vendors sell them. With the exception of retail, this distinction has little bearing on how the phrases are used in the majority of commercial contexts [1].

Usually, a financial system or a warehouse management system is used to monitor suppliers. Software solutions may be used to handle these operations efficiently. Vendor compliance checklists and vendor quality audits are common ways to manage vendors. Purchase orders are often used to enter into a contract with suppliers in order to purchase products or services [2]. Vendors may or may not serve as makers or distributors of products. Depending on whether the suppliers are also manufacturers, they could construct to order or to stock. "Vendor" is a phrase that is often used to refer to suppliers in a variety of sectors, including manufacturing, retail sales, and local government. The word often only refers to the immediate seller, or the organisation that receives payment for the items, as opposed to the original manufacturer or, if it differs from the immediate supplier, the organisation providing the service. There may be a variety of techniques for choosing suppliers depending on factors like price, quality, dependability, deliver, and many more. In order to pick the best and simplest approach for choosing vendors for the gas turbine engine, this study reviews the best vendor selection methods used by numerous industries, including the aircraft and shipbuilding industries.

Researchers have been interested in supplier selection issues since the 1960s, and research studies in this field have grown. Several authors have highlighted the significance of supplier selection by highlighting the influence that decisions made at every stage of the supply chain, from the acquisition of raw materials to the delivery of finished goods to customers, have. Researchers have created several criteria, decision techniques, and models that address various parts of the supplier selection process in order to assist decision makers or customers in making wise judgements with regard to supplier selection. The methodology and selection criteria for suppliers are discussed in this study. Based on the assessment, it would not be illogical to propose that the difficulties surrounding supplier selection need more attention in order to harmonise the mix of qualitative and quantitative factors in order to create the best criteria and procedure for choosing the best suppliers [3]. In order for a firm to find its perfect supplier, the process of supplier selection must be strategic. An efficient supplier selection process includes the following 5 steps:

Stage 1: Determine Business Needs

Determine what your company requires to manufacture its goods or provide the services it offers. Check to see whether there are any legislation or industry standards that your company must adhere to. If you manufacture products or provide services, you should be aware that your consumers and business partners may also demand your suppliers to adhere to the same standards that you do in order to maintain an acceptable level of quality throughout a product's life cycle.

There are internationally recognised certifications and standards that take into consideration the vendors or suppliers of companies operating in certain sectors. You should consider each of these while determining the demands of your company that prospective providers should meet [4].

Stage 2: Make a list of potential vendors

After determining your company's requirements, create a list of possible vendors. Going via your personal and professional networks is one of the simplest methods to identify new providers. To identify possible suppliers, you may also browse ads in industry journals, go to trade exhibitions, and participate in business forums [5].

Use the internet to your advantage by looking for forums that are relevant to your sector and visiting business-to-business marketplaces where you could locate local suppliers. Similar to your networks, the internet is a great resource for finding information on supplier reputation.

Stage 3: Determine your supplier selection criteria

To assist in limiting your supplier options, prepare a list that outlines what you and the company need from a provider. This may make the decision process simpler and more objective, as well as assist in identifying the differences between vendors. A set of priorities that you use to pick which supplier or vendor to choose is known as a supplier selection criterion. When searching for suppliers, you may wish to consider the following supplier selection criteria:

When searching for a supplier, the most fundamental and non-negotiable requirements for your company are product quality and safety, both of which your supplier should consistently uphold [6].

Flexibility - Should you need to make modifications to your orders in the future, the supplier's capacity to adjust to your (perhaps) shifting company demands may come in helpful.

Delivery: At the absolute least, a provider must always deliver on schedule and be trustworthy enough to let you know if there will be any unforeseen delays.

An unreliable or unpredictable supplier, on the other hand, might cause problems for your company. Reliability: A dependable supplier is a business partner who can significantly contribute to the success of your company.

Cost: Verify that the supplier's costs are within your allocated budget. Make sure that any cost-saving measures won't jeopardise the supplier's goods' reliability and safety. If your company has to do this in the future, you should also think about if there is a payment plan that would be optimal or acceptable to both sides.

Service quality - The level of service your supplier offers may set them apart from their rivals and make doing business with them enjoyable for you.

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CHAPTER 13

ADVANCEMENTS IN SUPPLY CHAIN MANAGEMENT

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The emergence of artificial intelligence (AI), big data, and growing automation in recent years have raised concerns about the nature of the future of labour, especially in the context of supply chain management. Whether supply chain management is dying is a hot topic right now. But I think that people are extremely interested in knowing whether they will be replaced by machines [1]. Though the solution is more nuanced than a straightforward yes or no, it is still a yes. However, let's go a little further to grasp all the factors at play before I respond to the two questions above. Let's define supply chain management first. The supply chain as we understand it today is the result of the convergence of several processes that must work together to finish a job. From firm to company, supply chain management differs in complexity and variety. For instance, some small businesses have to transport products from one warehouse to a distribution centre and then to a consumer. On the other end of the spectrum, major businesses have a greater number of considerations to make, such as ports, third-party logistics, warehouse distribution, inventory management, and fulfilment, to mention a few [2].

In actuality, just as technology has disintermediated other sectors, the supply chain is being disrupted and disintermediated. In essence, routine, repetitive jobs are now mechanised. Imagine that you are the manager of a warehouse that houses one million steel beams. In the past, you may assign a worker to go out and physically inventory your goods on a regular basis. It would take a lot of time, be potentially risky, and be challenging to guarantee absolute correctness. However, with AI and big data, robots, remote procedures, and other processes are automating operations like these. With more accurate predictive analysis, AI is also upending the supply chain, which is advantageous for monitoring and ordering supplies (e.g., how many steel beams will be needed in the coming months, when and where). Automation may also be used to forecast machine wear and tear so that replacement components can be installed before the unit breaks down, which disrupts the supply chain. To increase the effectiveness and predictability of supply chain management, sensors can give performance and efficiency data [3].

The food chain is changing.

Despite the fact that the present supply chain is undeniably disturbed, it is evident that supply chain management is not extinct. Like it always has since its conception, it is changing. However, because of the Fourth Industrial Revolution, we are going through this disruption on a much wider scale and at a much quicker rate. Because of this disturbance, there are corresponding natural worries. In particular, individuals are concerned that these developments may result in their displacement and unemployment. Any new technologies that promote automation and efficiency will continue to be a part of supply chain management in the future. Here are a few more software developments that experts believe are imminent:

AMRs have been explored by industry leaders in supply chains like Amazon in the past, but they haven't yet gained traction in the market. While WMSs will still be used to schedule tasks like loading and unloading, AMRs may become a useful tool for choosing process optimization [4].

Manufacturing and collaboration software solutions are reasonable investments for truck manufacturers and shippers that are planning for a recession. Trucking firms are able to increase their market monitoring, automate procedures, and reduce expenses thanks to more sophisticated technology.

The inability of current inventory software to provide the analysis required to keep up with scattered inventory makes it more difficult for businesses to meet cutting-edge shipping expectations. Businesses may increase order fill rates and maintain minimal inventories thanks to a method called distributed inventory flow forecasting (DIFF), which forecasts the movement of supplies. Delivery using drones and autonomous vehicles: Companies can solve a number of problems by using driverless and drone delivery methods. By reducing the amount of human interaction, this not only reduces expenses but also increases access to rural regions that are far away and challenging to reach. While some have previously expressed scepticism about this technology, it might be a useful tool in the future, especially given the growing lack of qualified human drivers [4].

For several sectors, 3D printing has completely changed the landscape. Replacement components for items made of metal and plastic may be produced and duplicated using 3D printing. Companies may work with neighbourhood 3D printing businesses to create and deliver things in a couple of days rather than keeping them in stock in a big warehouse to be sent across the globe. Customers are more satisfied as a result of the advantages of inventory and space management being transferred to them.

Blockchain. There is often a lack of openness in the transaction of products between nations. Even without considering the difficulties of processing a higher volume across several entities, invoices and shipments might take several months to complete. By enhancing traceability and security, blockchain has the potential to revolutionise the supply chain sector. Despite being well known for its capacity to support cryptocurrencies, the blockchain may also help businesses by handling contracts and agreements and keeping an eye on money and other items [5]. Each step of the end-to-end process requires innovation from supply chain management. Supply chain executives need to take the following actions in order to succeed in this:

Gain visibility. Effective management depends on having access to real-time data on the handling of products and materials at every point in the supply chain. The ability to see the whole supply chain enables businesses to reassure customers that the goods they are purchasing have been procured in a way that is both socially and environmentally responsible. Ask H&M, which has made public a map of its supplier factories. Decisions regarding their purchasing habits may be made by customers with better knowledge. Through the use of this information, businesses can keep things under control, uphold rules and regulations, and address issues as soon as they arise.

Make future predictions. Predictive analytics don't have a crystal ball, but they can see trends to prevent problems from happening in the first place, satisfy demand without overstocking, and save expenses. Shippers need to be ready for anything given the present trading climate. Having sophisticated mechanisms in place that expand possibilities when a provider is not accessible is one method to combat this.

Work with data teams. Strong technology investment is required, but not simply at the material level, for supply chain management to succeed in the future. Organizations fail when data teams aren't given committed human resources. This is so that they can provide a variety of dynamic benefits that go beyond just putting new systems in place. They carefully consider the demands of the company while analysing the data, producing insights and suggesting development ideas [6].

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