DIGITAL PRESCRIPTIVE MAINTENANCE

Disrupting Manufacturing Value Streams through Internet of Things, Big Data, and Dynamic Case Management

A PEGA MANUFACTURING WHITEPAPER

Dr. Setrag Khoshafian
and Carolyn Rostetter
Pegasystems Inc., USA

The focus of this book is the digitization of maintenance that is prescriptive, especially through Dynamic Case Management. The book will also highlight a number of use cases from key industries that are leveraging the Internet of Things (IoT, aka "Industrial Internet," "Internet of Everything," and "Machine to Machine"[1]).

The disruptive digitization approach to maintenance from descriptive, to predictive, to prescriptive with digitized decisions, cases, and IoT applies to any industry, including aerospace, defense, automotive, energy and utilities, agriculture, mining, and consumer products, such as home appliances, lighting, thermostats, televisions, healthcare devices, and wearables.

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Introduction:

Digitization Forces Optimizing Manufacturing Value Chains

Digitization is disrupting manufacturing by using innovative approaches and agile business processes to optimize end-to-end manufacturing value chains. The following chapters focus on a novel approach to **Total Productive Maintenance**[2] processes that leverage three essential digitization forces: **Internet of Things**, **Big Data analytics**, and, of course, **Dynamic Case Management**, which is also referred to as adaptive case management.[3]

TRADITIONAL MAINTENANCE MEETS THE FUTURE

The holistic approach to maintenance is now augmented with Things (making up the Internet of Things) that are increasingly intelligent and responsive. This advanced holistic approach offers significant advantages over using traditional (descriptive), preventive[4], or predictive[5] models individually.

Traditional maintenance tends to be reactive-responding to failures in equipment or devices after the fact. This traditional, reactive approach of describing failures after they've occurred (productive maintenance) is the worst-case scenario for maintenance: reacting to failures in equipment or devices after the fact. Preventive maintenance empowers operators to carry out continuous maintenance.

A disruptive model harnesses the power of connected devices and the Internet of Things in a way that changes the dynamics of conventional Total Productive Maintenance (Total Productive Maintenance), which defines maintenance as simply minimizing machine downtime. Incorporating intelligent software into these connected devices (Things) is proving to be a key enabler for diagnostics and proactive maintenance. Each layer of device and software creates a greater level of control and efficiency.

To truly tap the power of the Internet of Things, big data analysis, and dynamic case management, let's look at the role of prescriptive maintenance in the total productive maintenance processes.

PRESCRIPTIVE MAINTENANCE

Prescriptive maintenance goes beyond the realm of productive, preventive, and predictive maintenance. Descriptive focuses on what happened in the past.

Predictive analytics discovers potential options for the future. Prescriptive maintenance leverages all these approaches and capabilities. **The realm of what should happen and the execution of optimized maintenance strategies is precisely the realm of prescriptive maintenance**. With prescriptive maintenance, devices, in collaboration with operators, are proactive participants in their own maintenance.

Several trends are merging to disrupt manufacturing—especially in regards to maintenance. These include the main forces of digitization (Social, Mobile, and Cloud), Internet of Things, and Big Data analytics.[6]

Chapter One:

The Role of Big Data

HARNESSING THE POWER OF BIG DATA GENERATED BY THINGS

Increasingly, Big Data is becoming "Thing" Data, with connected devices in manufacturing value chains generating enormous amounts of information. Potentially, sensors on edge devices can continuously record their behavior and status. These event data are filtered and aggregated in Big Data repositories managed through NoSQL databases. Big Data analytics are then used to prescribe maintenance tasks executed in the context of dynamic cases.

Mining and discovery from Big Data allows proactive diagnostics and fixes that often anticipate and prevent incident events, which would otherwise require expensive maintenance processes.

DYNAMIC CASE MANAGEMENT

Perhaps the most important pillar supporting prescriptive maintenance is **Dynamic Case Management**[7]. Dynamic Case Management is perfect fit for Digital Prescriptive Maintenance (Digital Prescriptive Maintenance). With Dynamic Case Management, maintenance tasks include predetermined repetitive process fragments as well as unplanned and ad-hoc tasks.

End-to-end maintenance case management is quite complex and involves several types of workers (including Things and Robots), organizations, and tasks. Therefore, Dynamic Case Management requires a number of key capabilities:

- Digitization of value chain stages for end-to-end maintenance
- Planned and ad-hoc tasks that execute in the context of maintenance processes within a case hierarchy
- Decision management that leverages various types of business rules as well as analytical models (predictive or self-learning, also known as adaptive)
- Predictive models to determine the next best action for maintenance: the Big Data generated and aggregated from sensors is a critical source for predictive analytics
- Just-in-time integration with enterprise applications

FROM TOTAL PRODUCTIVE TO DIGITAL PRESCRIPTIVE

Total Productive Maintenance is an important phase in the overall end-to-end product manufacturing lifecycle. Total Productive Maintenance has its roots in the Toyota Production System[8], and historically it has focused on improving **Overall Equipment Effectiveness** in the plant.

Overall Equipment Effectiveness is a common calculation of Performance x Availability x Quality, and the work cells in every plant focus on making that number better. Traditionally, Total Productive Maintenance is holistic and inclusive: manufacturers and operators collaborate to maintain devices or equipment. The objective of Total Productive Maintenance is to create a self-directed team environment to engage employees in preventing equipment breakdowns, which ultimately leads to improvements in product quality and the ability to meet commitments to customers.

Embedded sensors, software, controllers, and connectivity are creating a digital revolution in manufacturing and aftermarket services, such as warranty and repair. Breakthroughs in networking, edge and fog computing, cloud technology, faster CPUs, cheaper memory, energy efficiency, and miniaturization are all converging to create low-cost processing power and data storage everywhere.

The fact is that there are now computers in machines, gadgets, wearable devices, and smart Things that stream data about their operations, performance, and conditions. These Things will generate exponentially more data

than people or applications. Translating all of that data into insights and intelligent decisions is the key to effective analytics. Manufacturers have an obligation to mine, leverage the detected patterns, and act (prescriptive) to avoid potential failures that could sometimes have serious consequences for people, the environment, and equipment.

Business rules, business logic, Big Data analytics, and algorithms are all important aspects of maintenance optimization that spans "Productive," "Preventive," "Predictive," and most importantly "Prescriptive." The intersection of all these elements brings us to the power of digital prescriptive maintenance. Without prescriptive maintenance, we pay an increasingly high price for the waste and lack of coordination between Things, people, processes, data, and technology.

Chapter Two:

Digital Prescriptive Maintenance

DIAGNOSING EVENTS BEFORE THEY HAPPEN

Digital Prescriptive Maintenance focuses on operationalizing what should be done while leveraging the various types of digital technologies we've laid out above.

Cast in terms of a formula, we define **Digital Prescriptive Maintenance** as:

- Total Productive Maintenance +
- Descriptive, Preventive, and Predictive Analytics of Equipment data for Maintenance +
- Automated end to end processes with Internet of Things sensors and Dynamic Case Management[9]

We have called this the "Process of Everything":[10] the orchestration of dynamic end-to-end dynamic cases involving people, applications, trading partners and Things (including Robots) as participants.

The evolution from traditional Total Productive Maintenance is a dramatic shift. Rather than define maintenance as simply minimizing machine down-time, Total Productive Maintenance takes a more proactive approach, using data to predict future events and diagnose potential problems before they occur. With Digital Prescriptive Maintenance, machines will predict potential failures and autonomously trigger maintenance—all with minimal human intervention.

DYNAMIC CASE MANAGEMENT FOR DIGITAL PRESCRIPTIVE MAINTENANCE

We mentioned earlier the salient features of Dynamic Case Management and its perfect fit for Digital Prescriptive Maintenance. Dynamic Case Management is used to automatically create a maintenance case with tasks that can be assigned to Things or people.

In some cases, the equipment maintenance or repair can be done remotely by software. Other situations require a technician to be dispatched, and if so, they can arrive armed with advance information about the problem and the right parts and tools to fix it the first time, all provided through the use of Dynamic Case Management.

With Dynamic Case Management, the case also is tracked from beginning to end to ensure the appropriate resolution. The case data can be audited and mined for subsequent knowledge management. For example, the root causes and conditions that contributed to the case event can be analyzed using predictive analytics to prioritize the next best actions to troubleshoot the problem, diagnose the underlying issues, and identify the most likely solution.

The machines (or Things) that are part of the Dynamic Case Management system become self-learning and over time can "take care of themselves," reducing the need for rework and manual efforts that plague traditional maintenance case work.

The critical ability to collect and analyze structured data feeds from machines and other sources, along with the ability to combine semi-structured and unstructured data (e.g. images, audio, and video) into the mix, is transforming the future of manufacturing and after-sales service.

Another important aspect of Dynamic Case Management for Digital Prescriptive Maintenance is the flexibility in having structured, semi-structured, as well as ad-hoc tasks in the context of end-to-end cases created by people or Things.

Case management gives everyone in the value chain a view into the stages and steps of the process from end-to-end. The Dynamic Case Management analytics and data visualizations capture the performance of the process, providing a virtual cycle of continuous improvement. Case tracking and resolution data will point managers and operators to additional opportunities to eliminate bottlenecks, streamline and simplify.

The biggest benefit of Dynamic Case Management is that the process is no longer static or dependent on reactive outside interventions to drive improvements. With Dynamic Case Management, optimized, dynamic processes built-in to the system drive improvements. In short, the sum of the parts is now greater than the whole: manufacturers are simultaneously improving cycle times, quality, productivity, and the customer experience, which in turn reduces costs and risks, thereby yielding tangible bottom-line results.

Most importantly, Dynamic Case Management allows different categories of maintenance work to be automated, monitored, and optimized. This is discussed in the next chapter.

Chapter Three:

Maintenance Work Automation

TRANSFORMING AND DISRUPTING MANUFACTURING PROCESSES

Digital Prescriptive Maintenance is transforming and disrupting manufacturing processes. Dynamic Case Management is the core capability that allows Digital Prescriptive Maintenance operationalizes what should be done to optimize maintenance. The value proposition of dynamic case management can be summarized as follows.

DYNAMIC, HOLISTIC, AND ORGANIZED AUTOMATION

Maintenance is all about organizing and executing tasks that are typically work orders executed by different participants. These participants include in-house operators, contractors, as well as skilled engineering experts from the manufacturer or supplier. With Dynamic Case Management, the maintenance case involves multiple workers, operators, departments, and applications. The tasks and content is coordinated and automated by the underlying Dynamic Case Management maintenance solution. In an overall value and supply chain, each department and team can focus on a subcase contributing to the overall objective of the parent maintenance case.

NOTE: The Dynamic Case Management is essential for the prescriptive (what should be done) orchestration of all planned maintenance, ad-hoc maintenance, and as well as maintenance that reflect changes in manufacturing processes.

SOCIAL, COLLABORATIVE, AND FLEXIBLE

Digital Prescriptive Maintenance involves content, documentation (including text, images, and video), and continuous collaboration to achieve the objectives. Dynamic Case Management allows documents and content for maintenance be aggregated and referenced in the context of a specific case. Furthermore, Digital Prescriptive Maintenance case workers and managers can leverage discussion streams, synchronous exchanges or chats, knowledge wikis, and opinion blogs —all within the context of the dynamic case and its objectives. The case stays alive and continuously improves with innovative idea exchanges and queries, while knowledge about the product and service is aggregated for either reference or analysis down the value stream.

NOTE: Flexibility is critical. Exceptions happen. There are scheduled maintenance processes that can be controlled and automated through Dynamic Case Management. There are also ad-hoc tasks that maintenance technicians and managers can dynamically assign in the context of a maintenance case.

ENGAGING KNOWLEDGE WORKERS AND KNOWLEDGE-ASSISTED WORKERS

The knowledge workers[11] are the engineers and the cognitive maintenance subject matter equipment experts and often the authors of standard operating policies and procedures for maintenance. Traditionally they are siloed and do not engage in operational processes. That is changing with dynamic case management, and this very important category of knowledge workers is becoming increasingly more engaged in operationalized cases.

An even more important category of workers who are supported through dynamic case management are the knowledge-assisted maintenance workers.[12] This most common category of worker uses the decisioning, business rules, and situational/contextual execution of interactions in particular to help them complete their specific, contextual work within the case hierarchy.

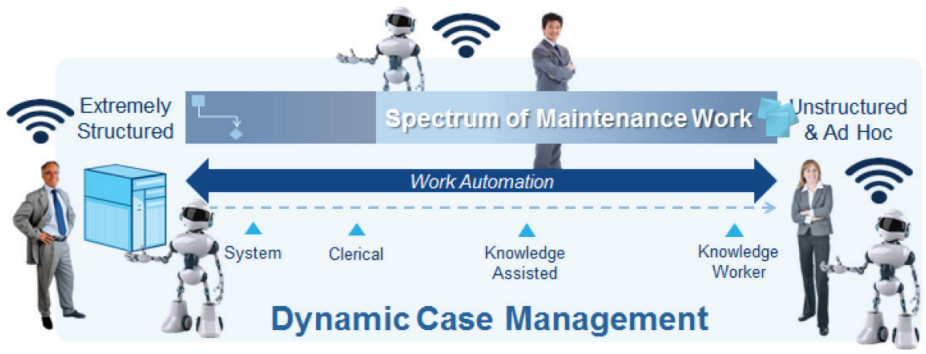

Figure 1: Maintenance knowledge work

COLLABORATIVE CASE MANAGEMENT

A case is the coordination and collaboration of multiple parties or participants that process different tasks for a specific business objective. The tasks are organized in a case hierarchy (subcases).

Case coordination requires a lot of collaboration among various case engineers, field workers, office workers and increasingly IoT or robotic workers to resolve the case. While processing these tasks, a case will gather content, often from multiple enterprise information systems or content management repositories.

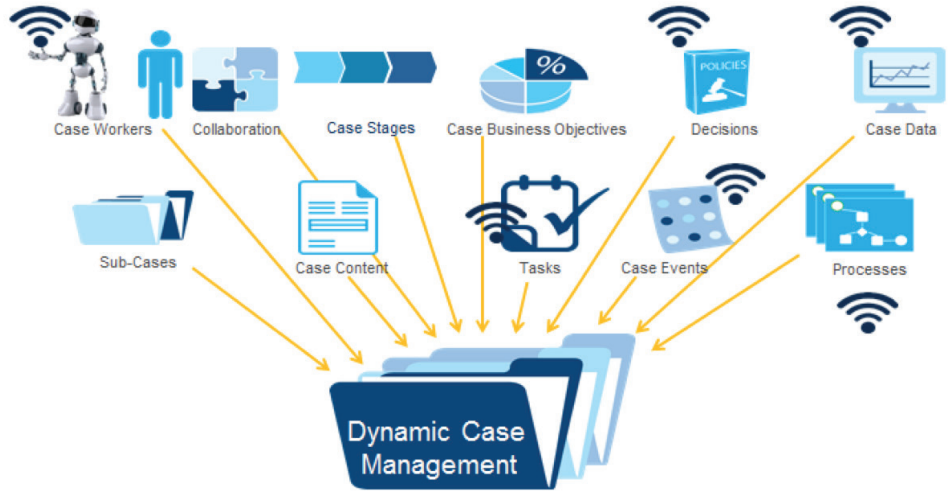

Figure 2: The anatomy of a dynamic case

Some of the tasks will be planned in predetermined process flows, while other tasks will be unplanned. Cases are therefore dynamic, adding or changing any of their elements, and responding to and generating events.

A dynamic case (or instance) in Digital Prescriptive Maintenance may include one or more of the following categories of tasks:

- **The device or equipment being maintained**
  Thus, a dynamic case instance can be associated with the maintained device for its life time. There will typically be many subcases and related case instances associated with this case. Thus all documentation, history, events as well as maintenance, warranty, and upgrade cases will be either embedded or associated with the main device case.

- **A specific planned maintenance case**
  This could be actually a subcase of the device case or a separate case that is related to it. There will be multiple planned maintenance case instances in the lifetime of the device. In addition to planned tasks there could be ad-hoc tasks (vs. entire exception cases) in the context of planned maintenance.
- **Unplanned and exception cases**
  Invariably there will be exceptional situations and unplanned incidents. Thus exception subcases will be generated with some semi-structure. There will be templates for handling the exception work and also provisions for ad-hoc tasks in the context of the exception case.
- **Related cases**
  The maintenance cases will often be related to or instantiate other cases. In maintenance one of the most important cases that will be instantiated for either planned or unplanned exception cases is the warranty case. This case will check the warranty policies and accordingly adjust the maintenance costs and reimbursements on the value chain (e.g. reimbursing dealers).

VEHICLE MAINTENANCE CASE EXAMPLE

The following illustrates a vehicle maintenance case and some of its subcases. The maintenance illustrated here includes tire, oil change maintenance, and anti-brake system. There will be tasks, caseworkers and subcases for each one of these (and other) components in a vehicle.

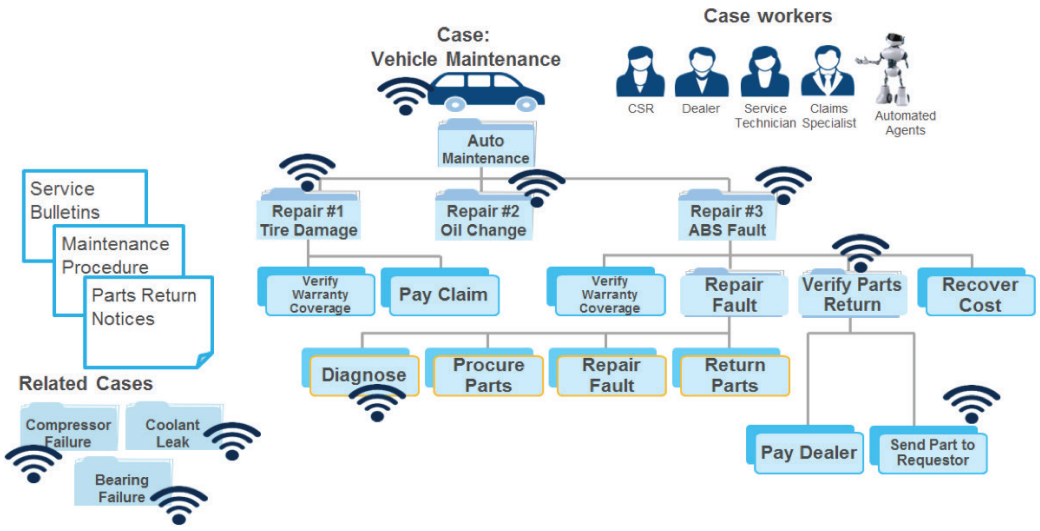

Figure 3: Vehicle maintenance dynamic case hierarchy

Throughout the maintenance case and its subcases there will be business rules and analytics models for decisioning to drive the next best maintenance actions. These are discussed in the next chapter.

Chapter Four:

Rules and Analytics

THE POWER OF BUSINESS RULES AND ANALYTICS IN DYNAMIC CASE MANAGEMENT FOR DIGITAL PRESCRIPTIVE MAINTENANCE

Business rules implement business decisioning logic and business policies. These rules drive the dynamic cases in Digital Prescriptive Maintenance solutions.

There are many categories and types of business rules, including decision trees, decision tables, constraints, and expressions. Business rules are declarative, which means the focus on business rules is on externalizing the business logic, as close to the business as possible, without worrying about execution time, execution method, or execution order.

The operating procedure policies that end up in business rules are derived from many sources, including policy manuals, the "heads" of experts or knowledge workers, and legacy applications. Examples of business rules that could be authored include: Expressions (e.g. for various calculations, such as volume, aggregate pressure, etc.), Decision Trees (IF – THEN), Decision Tables, Constraints (e.g. for actions when upper or lower bounds are violated).

DISCOVERABLE RULES AND PREDICTIVE ANALYTICS

Rules can also be discovered (aka "mined") from data of all sorts—including transactional event data, data warehouses, or increasingly Big Data repositories. The sources and types of data are heterogeneous. The on-demand or continuous sensor feeds of device status and event feeds provide a tremendous source of data for maintenance.

Predictive modeling techniques can be applied to this sourced data to discover device performance patterns in order to invoke or operationalize the discovered models in the context of Digital Prescriptive Maintenance solutions. Once patterns are discovered, predictive analytics can potentially "extract the knowledge," unlocking maintenance optimization strategies hidden in vast amounts of this digital information.

Furthermore, Dynamic Case Management enables the insight that is discovered to become actionable in Digital Prescriptive Maintenance.

EVENT RULES AND REAL-TIME ANALYSIS

One category of business logic—event rules—is especially important with intelligent Things. Employing event rules makes it possible to correlate and respond to events, subscribe to an event or state changes, and handle the events by any device category. This is an essential building block of Digital Prescriptive Maintenance.

In our vehicle maintenance case, one category of event rule is epitomized by temporal rules, which include service levels at either the dynamic case or task granule. Complex events can be correlated within temporal windows.

Digital Prescriptive Maintenance solutions (including the robots or Things in maintenance processes) can be adaptive: they can continuously learn and adapt from the events or the behavior of the device or its components. Leveraging the business rules and achieving this continuous real-time analysis for actionable decisions provides tremendous advantages for the maintenance value chain.

Solutions using the aforementioned business rules and analytics capabilities allow organizations to achieve preventive maintenance, detecting potential problems or degradation of equipment performance before it occurs.

Through analytics and business rules, tolerance thresholds can be observed, defined, and dynamically maintained in control.

VEHICLE MAINTENANCE CASE EVENT RULES

The following illustrates the intelligent "nervous system" of the vehicle maintenance case. Many types of rules capturing various policies will be used in the overall end-to-end case management of the vehicle maintenance case. Experts or knowledge workers will author some of these, while others will be discovered through predictive analytics.

Self-learning (aka machine learning or adaptive analytics) will also be leveraged to learn dynamically from the maintenance histories and behaviors of vehicles. These will guide the next best preventive or maintenance actions for any of the vehicles parts or components.

Figure 4: Business rules and analytics for Digital Prescriptive Maintenance

The rules or decisioning can be executed or leveraged by human works or Internet of Things participating in dynamic cases for maintenance. The next chapter delves deeper in IoT for maintenance.

Chapter Five:

Internet of Things Solving Real Problems

FOUR USE CASES FOR DIGITAL PRESCRIPTIVE MAINTENANCE

To be impactful, Internet of Things technologies need to solve real problems that typically involve multiple collaborating activities performed by people, systems, and Things. In other words, the Internet of Things needs orchestration through automated intelligent processes—the Process of Everything.

Let's look at four important Digital Prescriptive Maintenance use cases in which Internet of Things is managed by the Process of Everything.

1. **Things as participants in processes within dynamic cases for Digital Prescriptive Maintenance**
   Traditionally, the participants in business process management were humans (roles, skills, teams, etc.), systems (back-end applications or services), and business partners (for B2B processes). With the Internet of Things and the Process of Everything, Things (including robots) are also participants in processes.

   Things—manufactured or manufacturing devices—are becoming increasingly intelligent and self-governing. As a result, maintenance dynamic cases will include the Thing category of participants. In Digital Prescriptive Maintenance, Things (e.g. vehicle components) will start to diagnose and maintain themselves. Similarly robots will become active performers of maintenance tasks.

2. **Dynamic cases instantiated from thing events**
   One of the most pervasive use cases for Process of Everything in Digital Prescriptive Maintenance is the instantiation of a maintenance case when sensing (through IoT sensors) a failure or critical issue with the device. This happens, for example, when detecting high levels of CO, a problem with an axle, elevated temperature levels, or abnormal reduction in oil level.

   The intelligent Thing autonomously senses and then either directly, or through a brokering layer, activates an exception case (as discussed earlier). This typically includes monitoring by the back-office and dispatching field technicians to respond and resolve the problem.

   Within the processes executing in the exception case tasks and activities will be assigned to people as well as Things or robots. The dynamic case for Digital Prescriptive Maintenance orchestrates the people, the suppliers, the manufacturers as well as back-office operations such as warranty management.

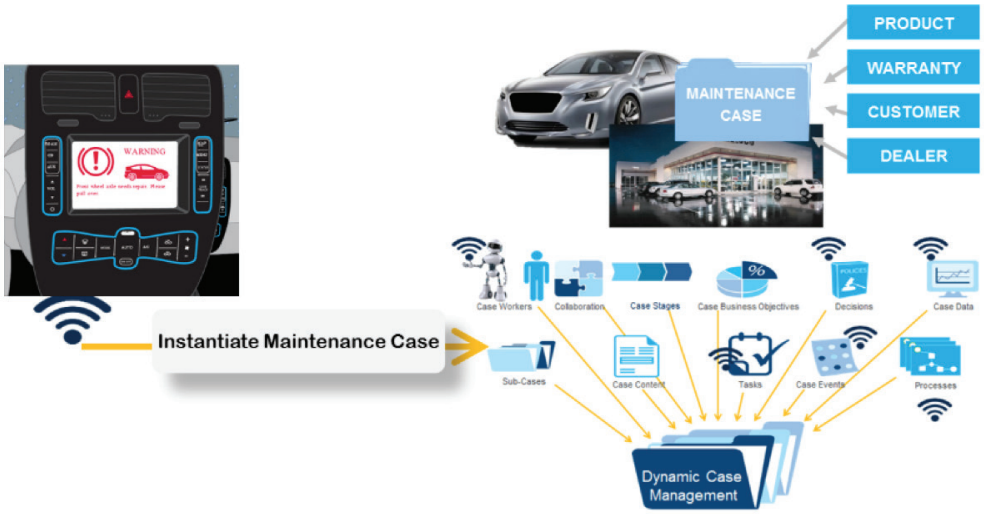

Figure 5: Digital Prescriptive Maintenance case instantiated from a sensed event

3. **Complex event correlation in real-time for Digital Prescriptive Maintenance**
   The previous use case elucidated an adverse event or state that was sensed (potentially analyzed at the edge or the device) to instantiate a maintenance case. Often it is not just an individual event but also a stream of events that indicate a potential problem that need to be addressed through maintenance cases. Sometimes you need to detect patterns involving multiple events over a period of time.

   The correlation of these events in a temporal window is a common maintenance use case. The correlation needs to happen real-time. For example if two temperature peaks occurred within five minutes, it could indicate a serious problem that needs to be addressed with an exception case for maintenance. The event correlations will be digitized through decisioning rules and the prescriptive action will be handled through instantiating the maintenance case.

4. **Predictive and Big Data analytics for Digital Prescriptive Maintenance**
   As noted above, devices are generating enormous amounts of information. As more equipment and manufactured devices come on-line through connectivity (the Internet of Things), the amount of data these devices generate will far exceed what human users of the Internet have generated thus far. Big Data will increasingly become Thing Data.

   Just having this raw data is not enough. This information can be mined and analyzed to better understand the device's behavioral characteristics and potential issues to maintain it intelligently. Unlike the previous scenario of real-time correlation of events, the data is aggregated over time and subsequently visualized and analyzed using predictive analytics models.

   NOTE: Mining the event history of the Thing, predictive techniques sometime discover patterns or correlations that are unexpected or unusual. The discovered knowledge and predictive models are then digitized in Digital Prescriptive Maintenance dynamic case solutions.

For Things to provide demonstrable value especially for maintenance, they need to be orchestrated with other Things, humans, and enterprise applications within end-to-end dynamic cases. This is discussed in the next chapter as the Process of Everything.

Chapter Six:

The Process of Everything

AUTOMATED INTELLIGENT PROCESSES AND DIGITAL PRESCRIPTIVE MAINTENANCE

Digital Prescriptive Maintenance leverages the intelligent business processes with decision management in automated dynamic cases, involving IoT devices as participants. More specially, with Digital Prescriptive Maintenance manufacturers gain access to the capabilities that follow.

SHOP FLOOR DIAGNOSTICS

Manufacturing Execution Systems[13] captures tremendous amounts of operational data that can be combined with data from the machines themselves, mobile devices, and the external environment. Mobile devices allow plant managers to monitor equipment and line efficiency through alerts, data visualizations, and real-time dashboards.

For example, a global manufacturer is using Dynamic Case Management to complement their standard Enterprise Resource Planning system and to improve their product quality and profitability. Product quality data is logged at every stage and every step throughout the production process. Defect tracking is then correlated with the series of events and machine data, such as temperature, humidity, speed, and other conditions to determine root causes and contributing factors. A case can be created to monitor and report on any actions required to correct the defect and prevent it from happening again.

This closed-loop feedback process allows the operators to make real-time adjustments to improve the first-pass yields and to reduce scrap and waste. The ability to troubleshoot and diagnose in real-time offers the manufacturer a competitive advantage in an industry challenged with low margins.

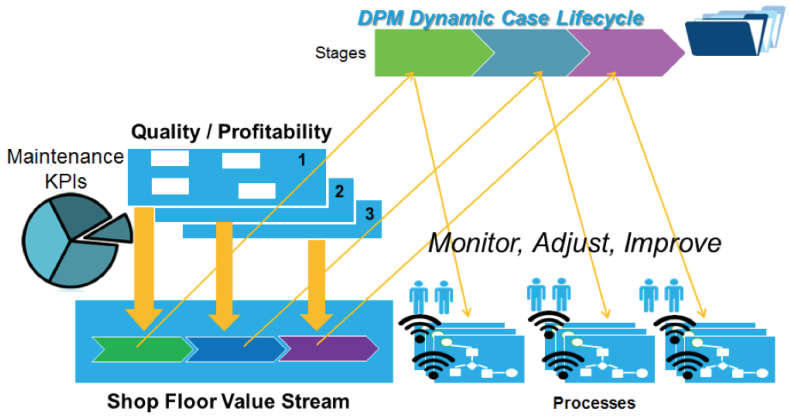

Figure 6: Shop floor value streams using Digital Prescriptive Maintenance case management

SUPPLY CHAIN ANALYTICS

Internet of Things, Big Data, and Fast Data[14] are transforming traditional supply chain management from end-to-end. Top leaders in supply chain and logistics are accumulating and analyzing vast amounts of data, including customer demand and the impact of external market trends and critical events. The supply chain today must leverage internal transactional data sources and external digital data sources, including both structured and unstructured data.

These supply chain experts and data scientists are improving the ability to predict the future and to react to high-risk or disruptive events in the supply chain. By combining Dynamic Case Management with Big Data,

the advanced planning teams use workflow and case management to optimize inventory levels. They can run scenarios using predictive and adaptive models to ensure the right parts are available at the right times in the right places. If a major unexpected disruption such as a fire or flood occurs at a factory or at a supplier's site, the supply chain can respond in real-time to avoid shortages, move inventory to another location, or find an alternate source.

Another global manufacturer is conducting a pilot to monitor data from social media channels such as Twitter and Facebook. Analyzing customer sentiment and perceptions will be used to enhance the design and manufacture of future products and to enhance service after the sale.

The scope of use cases with IoT in Dynamic Case Management for Digital Prescriptive Maintenance is extensive. The following are some other examples for manufacturing and supply chain management.

IOT DIAGNOSTICS

Things will either have on-board CPU and execution capabilities or be able to connect (e.g., via Bluetooth) to a device that has on-board execution for the device or Thing via low power connectivity. DPM will support:

- **Automatic Updates of On-board Device Software**
  Manufactured edge devices often have sophisticated software that can be updated remotely by the manufacturer.
- **Automatic Sense and Data of Measures from Edge Device**
  A manufacturer might need to gather data from the device or ping it for specific measurements and analysis.
- **Automatic Control for Maintenance**
  Devices can also be controlled remotely or through on board decisioning software.

IOT SUPPLY CHAIN AND PARTS RETURN

The edge device that needs to replace a defective device can be monitored from the supplier to the distributer or customer (e.g. via on board Global Positioning Satellite capabilities). Also, the defective device that needs to be replaced can be monitored for its return to the supplier or the Original Equipment Manufacturer.

IOT REPAIR OR PARTS VALIDATION

Once the repair or replacement is completed, the manufacturer can validate the fix and compliance to the warranty management policy.

These use cases clearly illustrate a new disruptive dawn in manufacturing through Digital Prescriptive Maintenance.

Conclusion

New trends in digitization have begun to disrupt the manufacturing and industrial economy. A shift in business strategy is required to stay ahead of the curve. Digital Prescriptive Maintenance is replacing the old manufacturing practice of Total Productive Maintenance, and provides the capability to create faster, better, and more value for the customer with reduced cost and improved quality.

The new value paradigm demands a fresh look at supply chain and shop floor activities to include the **Internet of Things**, especially through the **Process of Everything**. Manufacturers need to be able to quickly analyze real-time events and act upon discovered models from Big Data within the context of end-to-end dynamic cases. The resulting Digital Prescriptive Maintenance creates value for the customer and the manufacturer—in fact the entire value chain—because humans and machines (aka Things) work collaboratively.

In conclusion, **Digital Prescriptive Maintenance** is bringing revolutionary changes to the manufacturing and high-tech industry. The capability to bring together Big Data, IoT, and **Dynamic Case Management** will propel the industry forward faster than anything we have experienced in our lifetime.

The next industrial revolution has already started; it's the disruptive digital revolution. To be an industry leader means to make the investments now and take the steps forward before the competition does. Simply analyzing what happened in the past is no longer good enough. Moving toward predictive and prescriptive insights is the key to success.

Leading manufacturers will anticipate what might or will happen in the future and make the best possible decisions to deliver optimal performance. Processes need to be more integrated and less siloed across the enterprise, and legacy ERP systems and custom applications are too costly and time-consuming to change.

Smart manufacturers are creating innovative solutions that harmonize everything across the digital ecosystem – interconnecting business processes, systems, data, people, and things.

About the Authors

SETRAG KHOSHAFIAN
Chief Evangelist and VP of Business Process Management Technology
Pegasystems Inc., USA

Dr. Setrag Khoshafian is one of the industry's pioneers and recognized experts in Digital Enterprises, especially Internet of Things Dynamic Case Management, and intelligent Business Process Management (BPM). He has been a senior executive in the software industry for the past 25 years, where he has invented architected, and steered the production of several enterprise software products and solutions. Currently, he is Pega's Chief Evangelist and strategic digital transformation thought leader involved in numerous technology, thought leadership, marketing, alliance, and customer initiatives. Lead author of 10 books and numerous articles.

The majority of his time is spent with Fortune 500 companies, specifically on their transformational journeys leveraging digital technologies (especially digital transformation, IoT, process improvement through Dynamic Case Management).

His interests and expertise spans all aspects of innovation in Digital Enterprises. This includes intelligent Business Process Management; Predictive & Adaptive Analytics; Dynamic Case Management; Social, Mobile & Cloud; Internet of Things or Everything (he coined the term Process of Everything); Service Oriented Enterprises; Digitization through BPM for Simplification, Legacy Modernization & Business Transformation; Real-Time Lean Six Sigma; Agile Methodologies & COEs; and Organizational Impact of Digitization with intelligent BPM.

CAROLYN ROSTETTER
Senior Director, Industry Principal
Manufacturing & High Technology
Pegasystems, Inc., USA

For nearly two decades, Carolyn Rostetter has been a Business Optimization Leader in some of the world's most respected organizations. As a Master Black Belt, she provides vision and experience in areas such as Productivity, Quality, Strategic Planning, Change Management, and Communications. She has led large scale Lean Six Sigma development programs in industries such as Banking & Finance, Media, and Entertainment & Manufacturing. Carolyn has successfully supported enterprise-scale programs such as Compliance & Regulatory Services, Net Promoter Score (NPS) for Client Services, Organizational Transformation, Revenue Management & Treasury Services, Application Portfolio Optimization, Master Data Management, as well as Vendor Evaluation Services. She is currently Pega's Industry Principal for Manufacturing and High Tech industries.

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