IMPROVEMENT IN PRODUCT DEVELOPMENT: APPLICATION OF BACK-END DATA

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Case Study

Abstract

Purpose – Working with Quality Management there is emphasis on moving efforts upstream, i.e. to work on improvements as early as possible in the design phases. Less is done on how to use, and work with, data from the back-end of the product development process to support upstream improvement. In this paper the purpose is to suggest practices on how data from the back-end of the product development process can be fed back to the early design phases as a basis for improvements. The case studied will have a special focus on how use of claim data, one type of back-end data, can support robust design methodology.

Methodology/approach – This paper is based on a case study at a medium-sized Swedish manufacturing company. The study has encompassed interviews, direct observations, participation, and document analysis. Interviews were semi-structured; the questions mainly addressing use of the back-end data in product development. Data collection was based on real-time feedback and observations in order to assess the outcome, and its contribution towards improvements in product development.

Findings – The back-end data, when analyzed and fed back into the product development process, aids in closing the product development loop from claims to improvement in the design phase. Further, the use of back-end data in improvement work extends the usage of the claim database to various users, e.g. designers or developers. This can be facilitated through the establishment of links from the claim database to existing tools such as FMEA. Finally, continuous reporting and use of back-end data creates awareness of improvement needs and provides an opportunity to monitor performance over time in relation to customer usage variations.

Research limitations/implications – The single case study approach limits the generalizability of the outcome.

Originality/value – The paper addresses an area that has not previously been explored in depth, namely the use of back-end data as a basis for upstream efforts. Principles of robust design methodology are applied in product development through systematic analysis of the claims data, where failures during product use stage are addressed in connection to noise factors.

Keywords – Back-end data, claims analysis, robust design methodology, product development

1. Introduction

Quality Management (QM) has been applied, enhanced, and modernized in the past two decades (Douglas and Judge Jr, 2001, Gibson et al., 2003, Sousa and Voss, 2002, Kaynak, 2003). Customer focus and continuous improvement, amongst others, have been mainly focused upon in terms of principles of QM (Hellsten and Klefsjö, 2000, Dean and Bowen, 1994). In one of the many definitions, QM is seen as a management approach characterized by principles, practices and tools, where each principle is implemented through a set of practices, which are then supported by a number of tools (Dean and Bowen, 1994). In applying such an approach, in the effort of achieving high customer focus, for example, organizations have moved towards involving customers in product design decisions, i.e. the front-end of product development process (Kim and Wilemon, 2002, Gruner and Homburg, 2000, Tollin, 2002). An example of a tool which can be applied is Quality Function Deployment, in order to design a product to meet spoken and unspoken customer needs (Cristiano et al., 2000).

Similarly, Robust Design Methodology (RDM) is also commonly applied at the front-end of product development process (Hasenkamp et al., 2009). The objective of RDM application is to design a robust product which is minimally affected by sources of variation in various stages of the product cycle (Andersson, 1996, Goh, 2002). RDM is to be ideally applied throughout a product creation process, where insensitiveness to process variations, or noise factors, are applied through systematic efforts (Arvidsson and Gremyr, 2008). A product creation process here indicates the typical stages of product, which are design, manufacture and usage (Hasenkamp et al., 2007). These stages are also known, in other instances, as product development, production and usage conditions. RDM has been widely argued as a useful methodology in the design stage (Park, 1996) in an attempt to create insensitivity to potential variations to be encountered at later stages of manufacturing and usage. A main challenge faced by designers and engineers in design stage is imprecise and incomplete information on design requirements and constraints (Qin, 2000, Wang et al., 2002). These constraints could be identified with the presence of unknown noise factors affecting products during use stage. Adopting the same characterization of QM, RDM could also be characterized by certain principles. These principles are implemented through practices, which are then supported by a number of tools. Hasenkamp (2009) have identified, based on the three principles of RDM, the associated tools, and more importantly, the lack of identifiable practices in the implementation of continuous applicability principle, which is the 'what needs to be done' (Hasenkamp et al., 2009).

One popular tool to support RDM practice is Design of Experiments (DoE), where control factors of a process or product are experimented at high and low levels, targeted at achieving an optimal output. As the name indicates, this tool is based on experiments, where factors in play outside the knowledge of designers are not taken into account, and furthermore such experiments are usually associated with high costs (Ilzarbe et al., 2008). Although front-end focused approach presents many benefits, there is an opportunity to expand the application of RDM by use of back-end data. Variations encountered during manufacture stage are fairly convenient to identify by designers and engineers as the product is still located within the premises of the manufacturer. On the other hand, variations encountered during the product use stage are not as convenient to identify. This is where back-end data, such as claims and warranties, take a valuable stance. Such back-end data deserves emphasis in terms of its usability in RDM, to facilitate identification of variations during product use stage.

The purpose of this paper is to suggest practices on how to apply back-end data, such as customer claims, to support a proactive RDM approach. Exploring and analyzing claim data is regarded one practice to understand and manage variations during product use. The findings are then used as feedback into the product development in order to close the loop. This results in two outcomes. First, a new practice will be introduced addressing the lack of practices of RDM in the area of continuous applicability. Second, an emphasis is given to the use of back-end data in the application of RDM. This paper is based on a case study at a medium-sized manufacturer in Sweden, where the practice of analyzing claim data has been tied to Failure Mode Effects Analysis (FMEA).

This paper is structured as follows. Section 2 provides the theoretical background in the related areas. The methodology of the case study is described in Section 3. The findings are presented in Section 4, followed by discussion in Section 5. The paper is concluded in Section 6.

2. Theoretical Background

QM is a management philosophy practiced with the use of various quality tools and techniques (Hellsten and Klefsjö, 2000, Bunney and Dale, 1997, Tari and Sabater, 2004, Bamford and Greatbanks, 2005, Andersson et al., 2006). In recent years, research on QM shows an increased focus on its practices, more than tools and techniques, and its relationship with organizational performance, customer satisfaction, productivity and quality improvement, and project management (Bryde and Robinson, 2007, Zu, 2009). QM practices are explained by Sousa & Voss (2002)(p92) as *' ... the observable facet of QM, where one practice, for example, Process Management, can be supported by techniques such as Statistical Process Control in order to support the QM principle of Continuous Improvement'*.

Robust Design Methodology (RDM)

Practices of RDM have widespread emphasis on the front-end of product development process in past years (Hasenkamp et al., 2009). Unfortunately, there is not enough emphasis on its relevance at back-end of product development process. The third principle of RDM is about continuous applicability, which says that robust design principles should be applicable in all stages of product development process. RDM is also described as an approach to reduce performance variation in products and processes (Andersson, 1996, Goh, 2002, Shoemaker et al., 1991). Manufacturing process variations are commonly identified, and understood at times, through application of certain tools, for example process control charts (Bersimis et al., 2007). In understanding and addressing these variations, process improvements are put in place to increase performances. On the other hand, product performance variations are not as easily visible. Many sources of variation exist in daily application of products, such as surrounding environment, product utilization methods, user variations and such. In order to acknowledge and understand such conditions, it is necessary to analyze field data of products. An appropriate channel to realize and utilize field data lays in the availability of information through customer claims data.

Identification of noise factors, uncontrollable and caused by sources of variation, affecting a system is crucial in RDM. Only then, awareness could be raised towards sources of variation, and settings of control factors that makes the design of products insensitive to noise factors can be identified (Tsui, 1992). These sources which result in variation in product performance are traditionally categorized as: manufacturing imperfections (internal sources), environmental variables (external sources), and product deterioration. Manufacturing imperfections is seen in unit-to-unit variation of products due to manufacturing process variations. Examples of environmental variables are temperature conditions, dust, vibrations and such. Product deterioration is seen in examples of wear and degradation of components over time during usage (Mekki, 2006, Johannesson et al., 2012).

Designing reliable products is achievable through understanding of the conditions in which products fail. Such conditions, or incidents in some cases, are most often related to noise factors. Back-end data from customer claims is one available channel to identify these conditions, and thereby capture noise factors. Failures, when associated with noise factors affecting products and thereby causing the failures, present an opportunity to improve the products. Application of back-end data based on RDM principles, therefore, could be supportive of improvements in product development.

Back-end Data in Product Development

In moving towards a customer-oriented business, many organizations have adopted various tools to understand customer needs, such as QFD (Shen et al., 2000), customer surveys (Peterson and Wilson, 1992), focus groups (Kaulio, 1998) and product seminars (Cooper and Kleinschmidt, 1986). These tools are appropriate for handling of data from front-end of product development stage. Front-end data such as customer demographics and locations, for example, are studied and applied in order to gather valuable information related to the needs and wants of customers before the development of products begin. In the opposite continuum of the development process is the back-end data. Back-end of product development process points to production data, as well as warranty claims data from customer during product use stage. Here, the back-end data focuses on customer warranty claims.

Warranty claims data was defined by Blischke et al. (2011) as *data collected during the processing of claims and servicing of repairs under warranty, where data are obtained from the post-sale support system for data collection* (Blischke et al., 2011). Processing of claims is one part of warranty management system, where data is collected during or after the physical return of products due to failures during usage by customers. There are various methods of data collection and data analysis applied in claims processing (Boersma et al., 2004). As an example, data collection may be done by quality responsible of the organization, or an external agent, namely a distributor, or service centers acting as middlemen. The claims data are then transferred into the organizations by storing in a database. This in turn, makes the content of claims data subjective to industries and products. Nevertheless, the claims data collected are normally grouped into categories relevant to the application of the data, such as (Blischke et al., 2011):

- Product related (inclusive of product design): Mode of failure, failed component, age, usage at failure, etc.
- Customer related: Operating mode, usage intensity, operating environment, maintenance, etc.

In both categories above, the specific details of the failures are connected to noise factors caused by environmental variables and product deterioration as defined in RDM. In the instance usage at failure, the information points to a certain condition the product were subjected to, which caused the failure. Such conditions are construed as noise factors. A broken leg of a coffee table could be due to loading of a heavy object onto the table. This leads to the noise factor of differing loads placed on the coffee table. An example of usage intensity is a rubber-band that breaks when it is stretched past its elasticity. The extent of the stretch is considered as a noise factor affecting the rubber-band. Therefore, failures modes are often connected to noise factors.

In order to systematically apply back-end data, claims data analysis are related to various goals and objectives (Blischke et al., 2011), for example, to extract information for assessing product reliability and to aid in new product development. Specific to the purpose of assisting in new product development, the views on claims data have moved from a traditional to a strategic view (Blischke et al., 2011). Information derived from the back-end data are strategically related to reliability and robustness of products, which is then used as a basis for competitive advantage of organizations in new product development. Similarly, such information is also deemed advantageous for the improvement of current products and operations (Blischke et al., 2011).

A process flow of claims data analysis, tied to a problem solving tool, is formulated in order to systematically use back-end data as input for improvement, as shown in Figure 1, adapted from Blischke et al. (2011). A number of quality tools may be used for problem solving, including PDCA (Plan, Do, Check, Act) cycle (Blischke et al., 2011).

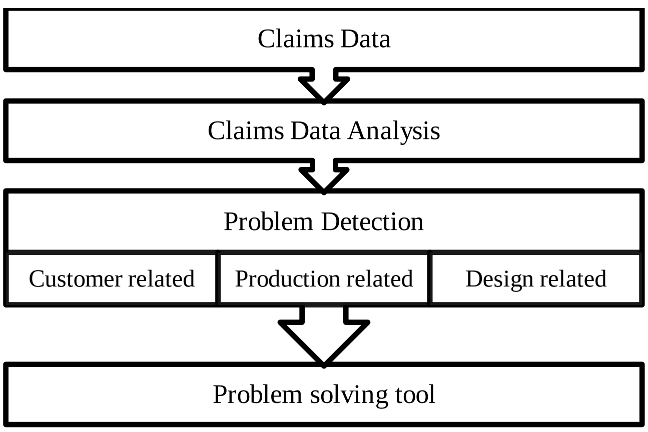

Figure 1: Process flow of Claims Data Analysis, adapted from Blischke et al. (2011)

Warranty claims data can be considered as the voice of the customers, but at the back-end of product cycle. These 'voices', when analyzed and interpreted, with the assistance of and integration with quality tools and methodologies, will translate to product improvement ideas to be applied at an earlier stage. An opportunity is presented to organizations to create a proactive mechanism in order to react quickly to deviations in product performance through implementation of a field feedback loop (Magniez et al., 2009). Such mechanism could be designed based on the customer warranty claims database to measure actual field reliability of products and generate valuable information to be fed back into the design process (Lawless, 1998, Meeker and Hamada, 1997, Meeker and Escobar, 2004, Thomas and Rao, 1999).

Customer claims analysis is also referred to as a feedback process in terms of customer dissatisfaction (Fundin and Bergman, 2003). The question has always remained on how to utilize the feedback to improve development of new products. In another word, how do we increase satisfaction of current customers by applying their own dissatisfaction feedback? This brings to light the ability to systematically analyze information or knowledge. Organizations aptly depend on two types of information, especially in the context of claims analysis, which are defined as 'codification' and 'personalization' (Hansen et al., 1999). Codification refers to information or knowledge transferred in databases, whereas personalization is information transferred between people. The lack of systematic approach in claims handling is identified as one of many challenges of effective management of claims. Other challenges include lack of appreciation towards customer claims and inability to integrate feedback into an appropriate quality management concept (Zairi, 2000).

One approach taken in addressing how to apply the dissatisfaction feedback is creating an information flow from back-end data to a problem solving tool. Examples of such tool could be a Six Sigma project (Fundin and Cronemyr, 2003). In the case study presented by these authors, customer claims were transferred through product fault analyzers within the organization towards a dedicated Six Sigma team to focus on an improvement plan based on the faults identified in the claims.

3. Methodology

The empirical setting is a medium-sized organization located in Sweden. The organization is a manufacturer of an internationally leading brand of coupling equipment for trucks and heavy trailers, operating for more than 60 years since 1951. The author has spent a year working in collaboration with this organization in terms of analyzing the customer claim data and establishing a connection between RDM practices and claim analysis.

The case study involved several data collection method (Yin, 2009). Interviews were conducted, face-to-face, with a number of main personnel directly responsible or involved in customer claim process, Project Management (PM), Quality and Environment (QA), and Technical, Operations, Research & Development (R&D), and Human Resource (HR), comprising of managers and engineers. A total of six interviews were conducted. Each interview lasted between 45 to 90 minutes. All interviews were recorded, and transcribed after. Further clarification was done by e-mail and telephone conversation, as and when needed. The questions were prepared in a semi-structured way, and contained open questions (Flick, 2009). The main questions were prepared beforehand, and used during the interviews. The follow-up questions were formulated based on the responses received from interviewees. The information gathered during interviews was then supplemented by document analysis of relevant documents made available by the interviewees (Flick, 2009). Those documents are the detailed description of the flow of product update process, new product planning process and the claim database.

Observation and hands-on experience were gathered during an activity of defective product inspection. This activity took a total of two work days. The defective products inspected were returned by customers through the claim system for various types of defects. A total of 85 units of coupling mechanisms were inspected and recorded. Finally, an affinity diagram, one of the 7 management tools, was applied in an exercise consisting of 5 participants as a method to compile unstructured verbal information (Shahin et al., 2010, Scupin, 1997). One question was presented to the participants for this exercise: What are the biggest problems in using claims data for improvements? The exercise contained several rounds of idea presentation followed by compilation of similar ideas into categories. This exercise was moderated by one external personnel, and was completed in three hours.

4. Findings

The existence of a customer claim process and database is well known and acknowledged by all interviewees. This could be pointing to the fact that none of the interviewee is new to the organization. Each of them has been an employee for more than 10 years, ranging from 13 to 30 years of service. On the other hand, when asked of how much is each of them involved in the claim process, with the exception of two Quality personnel, the responses were similar, which is, they are not at all involved. A few responded that they are unaware, or not informed, of the process flow of the claim system, or its findings. Back-end data, or field data, is a source of information specific to product usability and reliability (Petkova et al., 2005). Such data, raw or analyzed, is of critical value to an organization, especially to designers in R&D, project management (PM) leaders, and members of the sales team (Murthy and Blischke, 2000).

One of the functions of the PM leader is to schedule and perform a field test for all products developed within the organization.

> *We normally schedule field tests in November, to have a winter test. I talk to the drivers, ask them about different technical functions, and then I disassemble, take photos and store information in the field test database. Then we work on the issues, if any. (Project Management, interview)*

The field tests are seen as a requirement in the process of developing new products and simultaneously, confirming to the government regulations in assuring safety of the products. Such field tests are not only time consuming, but also expensive (Karim and Suzuki, 2005). Furthermore, the results obtained are dependent on selected drivers and known conditions during product use. Claim data, similarly, is an extended form of field data (Rai, 2009), where product failures occur due to certain noise factors unable to detect through a scheduled field test. In reality, various conditions, for example, drivers' lack of attention to the product or lack of knowledge of maintenance of the product, could lead to product failures. Such conditions may not present itself during a field test. Therefore, the claims data sharing within the organization possibly brings to surface questions or problems only designers could solve.

This was further strengthened during the interview with the R&D department, regarding the availability of claim data in processes of product planning and new product updates.

> *He (QA personnel maintaining the claim database) prints the report, and gives me the statistics. How many claims, which products, failure codes and costs. Today, I sit and read, try to understand what is wrong with the products. I read the comments on the claims. It's monthly statistics. We don't know the reason why. For us at R&D, we need to know what's the problem, what's the root cause. If it didn't work, why it didn't work? I need more statistics, more analysis, root causes. (Research & Development, interview)*

The R&D department is responsible for the new product development process. Claims data containing information related to customer usage and conditions (Blischke et al., 2011) present an unique opportunity to improve design of products. The feedback of such information to the front-end of product development allows the R&D personnel to act proactive in the development of new products or update of current ones (Magniez et al., 2009).

A worksheet named Bank of Ideas is maintained, where each employee is allowed to present ideas for product and process improvements. Most of these ideas come from Production personnel, for example, requesting a new jig for a certain process, change of specifications in an old drawing, request for a new tool required for a process, or improvement of a process flow. Such ideas are reviewed and approved, based on estimated costs of each idea, by one R&D personnel. Such initiative and involvement of an entire organization in product development activities, especially from employees directly involved in manufacturing of products, is favorable (Brown and Eisenhardt, 1995).

The Bank of Ideas also includes a number of improvements which originates from the customer claims process. This, however, does not occur consistently, or systematically. The trigger to analyze a customer claim as part of an improvement is an unusually high number of returned products, possibly from very dissatisfied customers. Lack of a systematized claim analysis process in addressing improvements clearly poses a challenge (Zairi, 2000). When the monthly claim statistics are generated and an anomaly is detected, where one product or part is claimed by customers in high quantities, or a certain customer has returned a batch of products under the same failure code, it is brought to the attention of everyone as a major quality problem. Such instances require the R&D and QA personnel to analyze and investigate the root cause of the problem. The analysis and investigation are then recorded as an improvement plan originating from the Bank of Ideas. Every idea that is generated and approved goes to the PM team for execution. One of the requirements of the PM process is to carry out FMEA for each product or part that is developed or improved. Therefore, certain claims analysis and investigation, triggered only by alarming quantities, are addressed and solved as improvement efforts (Fundin and Cronemyr, 2003).

The lack of structured and systematic analysis of claims was also identified as a result of the Affinity Diagram exercise in trying to establish the barriers to using claims data for improvements in the organization. These sentences were picked out from the first round of the exercise, where ideas are written down by each participant on what hinders usage of claims data for improvements.

- Lack of communication about the claims system between department
- There is little communication between claims handling and product development
- Claims system is not used by all departments
- Lack of structured process in handling claims
- No systematic linkages between claims and improvements
- Poor support on systematic analysis of claims

These suggestions to what are the problems in using claim data for improvements were combined into a single sentence in subsequent round of the exercise:

> *One of the biggest problems in using claim data for improvements is that there is a lack of structured and standardized process flow of the claim process internally. (Affinity exercise)*

It was unanimously agreed by all participants that a structured and standardized flow is required in the claims handling process, where linkages are clearly identified between departments (Blischke et al., 2011). Process ownership and responsibility shall also be identified in order to increase flow and content of communication regarding claims system and analysis towards improvements (Boersma et al., 2004).

5. Discussion

Claims Data

Availability of claims data through an internal database is acknowledged by all interviewees. The richness of the claims data, on the other hand, has not been debated yet. Also, the applicability of such data for improvements is still questionable, as for those who are not involved in the internal claims system have no involvement or authority over it at present.

The claims database contains line items of each claim, with details such as claim report number, customer code and failure code.

Claims Data Analysis

Currently, the analysis of claims data is restricted to general results based on the information derived from the database. Furthermore, the results are not communicated company wide. In order to create a practicable connection between claims data and product/process improvements, a systematic root cause analysis of claims could be included. This could be tied to a quality or problem solving tool such as PDCA, FMEA or DMAIC. The analysis of claims could be, first, categorized into product groups, where engineers or designers responsible for the product groups are involved in the analysis. Secondly, the claims of each product groups could be broken down based on failure codes, where failures are investigated and classified under types of problem, such as customer, production or design related (Blischke et al., 2011). This could narrow down the root cause analysis towards specific noise factors associated to the failures.

Problem Detection – Customer/Production/Design related

A systematic root cause analysis could point to accurate problem description. It is necessary to understand and segregate the problems by pinpointing the root causes in order to capture noise factors. There is an opportunity to include such details in the existing claims forms completed by customers during submission of claims. The problems, when classified in relation to customer, production and design creates various benefits, such as:

- Better understanding of external conditions (Rai and Singh, 2003)
- An opportunity to understand unknown noise factors (Wu and Meeker, 2002, Rai, 2009)
- Better understanding of own products and process (Attardi et al., 2005, Majeske et al., 1997)
- Ability to relate internal processes with external conditions (Buddhakulsomsiri et al., 2006)
- Expansion of information pool concerning product design (Wu, 2012)
- Creation of a robust solution to customer problems to improve reliability (Zhou et al., 2012)

Improvement Tool

Various quality or problem solving tools could be established in order to systematically address the problems. FMEA, as one problem solving tool, is used as an analytical tool to identify failures affecting performances of systems or products (Onodera, 1997). FMEA is popularly and increasingly applied in aiding product development, by addressing potential failures and its effects on systems or products (Smith, 2001, Kušar et al., 2004). FMEA is one approach to ensure product reliability (Ahmed, 1996), and therefore is strongly connected to product usage conditions and environment. This makes FMEA an appropriate tool to analyze back-end data such as customer claims.

The existence of FMEA as a widely used tool at the organization in product development presents a convenient opportunity. The claims analysis process flow could end in FMEA, upon identification of a customer/production/design related problem through claims analysis. FMEA could be tied to each of the problem detected in order to understand and analyze the failure mode and its effects. Details such as usage at failure could lead to identification of related noise factors. This, then, could allow for creating insensitivity to those noise factors as action plans in the FMEA. The case study findings show that FMEA is currently tied to selective claims within the organization, when deemed necessary, purely on case to case basis. Adopting the process flow of claims analysis, as presented in Figure 1, is suggested as one approach to creating a systematic and structured application of claims data for the purpose of product and process improvements.

6. Conclusions

Product development is widely dependent on front-end data such as new customer wants and needs. The wants and needs of current customers are most often not taken into consideration due to the lack of practices for utilizing dissatisfaction feedback systematically. Establishing a systematic practice to analyze and apply customer claims data towards improvement is one way to utilize back-end data to be supportive of product development. A well-defined claims analysis process is essential as a first step to appreciate the value of back-end data. Nevertheless, a well-defined claims analysis process alone is insufficient. It is necessary to create links between claims analysis and other processes within the organization.

The case study shows a lack of appropriate practice in order to link back-end data to improvements. Systematic analysis of claims data is suggested as a practice to support QM principles such as customer focus and continuous improvement. Such practice is seen to be supportive of RDM principles as well, namely, awareness of variations and creating insensitivity to noise factors. Understanding product usage and conditions in which it is used brings engineers and designers a step closer to identifying related noise factors. This practice is, then, linked to a problem solving tool to, not only investigate the failure modes, but also to address the related noise factors.

Back-end data is collected, stored and maintained in a database in the form of customer claims. Shallow analysis of claims data in a haphazard manner is a deterrent to application of claims data for improvements. This is due to the lack of a structured process flow for claims analysis. Adoption of a structured process flow allows for detailed analysis of claims leading to accurate description of problems. When problems are categorized in terms of its relation to customer, production or design, they could be addressed by respective teams assuming responsibility and ownership for each problem category. The problem solving step is then made viable with a tool such as FMEA to complete the claims analysis process. Here, FMEA creates the opportunity to investigate failure modes of products in usage resulting in claims. These failure modes are often related to noise factors products are subjected to during use stage. Understanding and addressing the noise factors allows for an informed decision on action plans. This complies with the principles of RDM, namely awareness of variations during product use stage and creating insensitivity to the noise factors identified.

A systematic analysis of claims data through adoption of the claims analysis process flow is suggested as a practice enabling application of back-end data for improvements. This practice is supportive of continuous applicability area of RDM. It further emphasizes the use of back-end data as feedback into product development through systematic claims analysis process based on RDM principles.

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