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Developing a System for Sustainable Product Design and Manufacture

Devdas Shetty
School of Engineering and Applied Sciences
Dean and Professor
University of the District of Columbia
Washington DC, 20008, USA
Devdas.shetty@udc.edu

Abstract

Research studies confirm that embracing sustainability in product design and manufacturing not only yields environmental improvements, but offers key business benefits. There is an increasing pressure to adopt a more sustainable approach to product design and manufacture. Organizations that are *actively engaged* in sustainable product design and development cite impressive levels of improvement over their poorer performing peers in product innovation, quality, safety and revenue growth alongside anticipated environmental and energy gains. **S**ustainability in design and manufacturing has a lot to do with "doing better with less," and embracing a broader view of product development, and examining full lifecycle of the product and the impact that its design, manufacture, performance and disposal can have across not only on business, but on the environment and society, as well. The process of rethinking a product's design so that it is more durable contains fewer parts and easily packaged and recycled also drives innovation and quality. The goal of sustainable product design (SPD) is to produce products and/or to provide services, which are sustainable and achieve their required functionality, meet customer requirements and are cost effective. In other words, SPD is about producing superior products and/or services that fulfil traditional criteria as well as sustainability requirements. The requirement to develop sustainable product is one of the key challenges of 21st century

This paper describes a system that identifies sustainability related performance measures for products in terms of:
a) Sustainable product design by robust design
b) Sustainable design by quality of service.

The first case study is on a laser based measuring instrument which supports the theory of sustainable product by robust design techniques The objective of the robust design study is to find the optimum recommended factor setting for the surface roughness analyser to minimize the variability in the readings. This instrument relies on the spread of the laser light on the work piece to determine surface roughness; therefore, the analyser's reliability depends primarily on everything involved with the laser and its path. There are a minimum number of parts to achieve this function since the laser can scan over the work piece, substituting functionality in place of additional parts. The use of surface roughness analyser for online measurement of surface finish and continuous online monitoring and control with a feedback provides the robustness in quality and sustainability.

The second case study, which is on elevator quality of service, is considered to support the theory of sustainable design by quality of service. This example shows how the design considerations are influenced and closely linked to the quality of service and maintenance. To support the theory of sustainability by quality of service, this case study examines elevator design and maintenance and recommends a new procedure based on Root Couse Analysis resulting in Elevator Condition Index (ECI). ECI is a new procedure and is applied based on original equipment reliability, projected average life cycle of key wear components, number of run cycles since maintenance was last performed on each component, cost of emergency repair vs. cost of maintenance vs. likelihood of failure. It supports service based on prognostics rather than routine service cycles.

Sustainable design and manufacturing is possible if we deploy the virtual engineering tools to monitor and service manufacturing machinery so that the sustainable benefits are maintained throughout the product design cycle. The choice of a workplace structure depends on the design of the parts and lot sizes to be manufactured as well as market factors, such as the responsiveness to changes. Designers should be aware of the manufacturing consequences of their decisions because minor design changes during the early stages often prevent major problems later. As a part of product performance evaluation, the use of capability index to maintain process

quality can lead to beneficial results.

Index Terms—Sustainable design, robust design, elevator quality of service, simulation based design support.

Introduction

Sustainability is a subject that has received lot of attention over the past several years. **S**ustainability in design and manufacturing has a lot to do with "doing better with less," and embracing a broader view of product development – looking at the full lifecycle of the product and the impact that its design, manufacture, use, and retirement can have across not only on business, but on the environment and society, as well.

Sustainability Literature Review

Manzini and Vezzoli [1] argued that the design competencies should move towards those of the 'strategic design', thus introducing the concept of 'strategic design for sustainability': the design of an innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands, while re-orienting current unsustainable trends in production and consumption practices. In their work, they have discussed services that provide 'added value to the product life cycle', provide 'final results to customers', and provide 'enabling platforms for customers'.

Kaebernick et al. [2] indicated that sustainability in the development and manufacture of new products is a strategy that is widely accepted in principle, although not yet widely practiced. The integration of environmental requirements throughout the entire lifetime of a product needs a new way of thinking and new decision tools to be applied. They described the concept of an approach to product development, based on a paradigm for sustainable manufacturing using examples of methodologies and decision tools representing the most important sources of environmental impacts of a product.

Hauschild et al. [3] reviewed the state of Life Cycle Assessment (LCA) introducing the central elements of the methodology and the latest developments in assessment of the environmental, economic and social impacts along the product chain. They provided an overview of Design for Environment (DFE), specifically focusing on the tools for design for disassembly. They presented a systematic hierarchy for the different levels at which environmental impacts from industry can be addressed by the engineer in order to improve the eco-efficiency of the industry. They strongly concluded that industry must include not only the eco-efficiency but also the product's environmental justification and the company ethics in a life cycle perspective in order to become sustainable. In the outlook it was concluded that present drivers seem insufficient to create a strong move of particularly the small and medium-sized enterprises in the direction of sustainability, and a need for stronger legislation and for education and attitude building among future citizens and engineers is required.

Roy [4] argued that the concept of sustainable product-service systems is distinct from the ideas of cleaner production, eco-design and design for the environment. The concept goes beyond the environmental optimisation of products and processes and requires radical and creative thinking to reduce environmental impacts by a factor of between four and 20 times while maintaining an acceptable quality of service. Sustainable product-services consider alternative socio-technical systems that can provide the essential end-use function, such as warmth or mobility, which an existing product offers. He outlines four types of services —result services; shared utilisation services; product-life extension services; and demand side management. Sustainable product-service systems attempt to create designs that are sustainable in terms of environmental burden and resource use, whilst developing product concepts as parts of sustainable whole systems, which provide a service or function to meet essential needs.

Rathod and Vinodh [5] reported their research carried out for ensuring sustainable product design by the integration of environmentally conscious quality function deployment (ECQFD) and life cycle assessment (LCA) approaches. They defined sustainability as the capability of an organization to maximize resource efficiency for ensuring clean and green atmosphere. The implementation study was carried out on a manufacturing organization.

Jawahir et al. [6] demonstrated that achieving sustainability in manufacturing requires a holistic view spanning not just the product, and the manufacturing processes involved in its fabrication, but also the entire supply chain, including the manufacturing systems across multiple product life-cycles. This requires improved models, metrics for sustainability evaluation, and optimization techniques at the product, process, and system levels. They presented an overview of recent trends and new concepts in the development of sustainable products, processes and systems, in particular, recent trends in developing improved sustainability scoring methods for products and processes, and predictive models and optimization techniques for sustainable manufacturing processes, focusing on dry, near-dry and cryogenic machining as examples.

Gehin et al. [7] explained their vision of why and how to integrate End-of-Life (EoL) strategies in the early design phases, and what tools to apply 3R strategies, considering the evolving architecture of the product, and the translation of transversal information into design criteria. Integrating constraints from EoL strategies into the early phases of design is one important aspect that needs to be improved. They proposed combining this idea with principles from concurrent engineering to develop design aids which permits designers to compare their products to “Remanufacturable Product Profiles”. The strategy is to develop tools to help designers make optimal decisions while designing a product considering 3R strategies: Reuse, Remanufacture and Recycle. Most of the Original Equipment Manufacturers recycle or subcontract reverse logistic and EoL treatments.

Why Sustainability Is Important?

Concerns about rising energy costs and efficient use of resources; availability of, access to, and/or price volatility of critical materials; and the potential risks, opportunities and costs posed by industrial and consumer waste, are just a few of the reasons that manufacturers may want to begin thinking more seriously about sustainability. Research confirms that embracing sustainability in product design and manufacturing not only yields environmental improvements, but offers key business benefits. In addition, environmental and/or societal benefits must be paired with financial benefits in order to truly succeed. The good news is that manufacturers are increasingly finding that there are key business benefits associated with “going green.” This means, sustainability is about doing the right thing, financially.

Sustainability Provides Financial Benefits

Organizations that are *actively engaged* in sustainable product design and development cite impressive levels of improvement over their poorer performing peers in product innovation, quality, safety and revenue growth alongside anticipated environmental and energy gains. Research based on in-depth interviews and survey responses from product designers, engineers, manufacturing executives, and sustainability experts from over 125 organizations worldwide, reveals that embracing sustainability in product design and manufacturing not only yields anticipated environmental improvements, but drives greater innovation, quality improvement, energy savings, and revenue growth, as well. Moreover, a company doesn’t have to be expressly involved in the development of “eco-friendly” products to reap these benefits.

The sustainable product design and manufacturing process itself is where many of the opportunities to improve business and environmental performance reside – and where significant savings and benefits can be realized. For example, eco-efficiency efforts can result in lower production costs and greater operational efficiencies, as well as reduced shipping and transportation costs. Taking a more sustainable approach to product development also lowers risk (i.e. less threat of a product recall posed by the “hidden” presence of toxic materials in the supply chain) and reduces uncertainty (i.e. more sustainable sourcing results in less exposure to potential supply chain disruptions due to resource scarcity or materials shortages). Furthermore, the process of rethinking a product’s design so that it is more durable or more easily recycled; or so that it contains fewer parts, less packaging or more recycled content – also drives innovation and quality improvement. Sustainability is not only good for the environment; it is good for business too. The organizations can effectively incorporate sustainability in their business efforts. With respect to sustainable product development, the application of sustainability principles, tools, and strategies during the product design phase is critical, since it is during this early phase of the product lifecycle that decisions can have the greatest impact on cost, performance and sustainability.

Sustainable Product Design Approaches (SPD)

The goal of SPD is to produce products and/or to provide services, which are sustainable and achieve their required functionality, meet customer requirements and are cost effective. In other words, SPD is about producing superior products and/or services that fulfil traditional criteria as well as sustainability requirements. The integration of environment with traditional product criteria to produce superior products. An approach known as, triple bottom-line approach proposes that reliable product design includes supply chain mechanism, consisting of economics, green technology, and ethics. The products and/or services are developed to be more sustainable in a Triple Bottom Line (TBL) context. (Reference Figure 1) This is interpreted as achieving an optimum balance between environmental protection, social equity and economic prosperity, while still meeting traditional product requirements, e.g. quality, market, technical and cost issues, etc.

Figure 1. Business Impact of Sustainable Product (Source: Four Winds Research (copyright 2012)

1. Robust Design Approach

Robust design is a systematic method for delivering a high quality product when ambient conditions vary a lot. The method can greatly improve an organization's ability to meet market windows, keep development and manufacturing costs low, deliver high quality products. It is a methodology where quality is brought in concurrently with product design and development. Quality is defined as satisfying customer requirements or failure to deliver it. Impact of poor product quality is far greater than what appears in the first instance. It is expressed in monetary terms as quality loss and recognizes failure to meet customer expectations that may result in direct cost to the customer. It will also result in customer dissatisfaction, which means less future sales, reduction in market share, necessitating higher marketing and advertisement costs. In addition, direct supplier losses in terms of scrap, rework, inspection, warranty are passed on to the customer.

In order to get a full picture of robust design, it is necessary for us to understand the implications of quality. The ideal quality a customer can expect is that every product delivers the target performance each time the product is used under all intended operating conditions, throughout its intended life. Traditional concepts of reliability and dependability are a part of the definition of quality. This definition of quality of a product can be easily extended to processes as well as services. The entire discussion of the robust design method is equally applicable for processes and services. Cost of delivering a product is broken into three areas: (i) operating cost (ii) manufacturing cost (iii) research and development cost. Operating cost consists of the cost of energy needed to operate the product, environmental control, maintenance, inventory of spare parts and units.

A manufacturer can greatly reduce the operating cost by minimizing the product's sensitivity to environmental and manufacturing variation. Important elements of manufacturing cost are equipment, machinery, raw materials, labour, scrap, rework, etc. Manufacturing cost could also be reduced not only by designing the robust part, but also by designing the manufacturing process robust by reducing process sensitivity to manufacturing disturbances. Research and development takes time and substantial amount of resources. The cost of research and development can be kept low by a robust design approach, because it improves the efficiency of generating information needed to design products and processes, thus reducing development time and resources needed for development. Higher quality means lower operating cost and vice versa.

Design of experiments is one of the quality techniques used to optimize the performance response. Design experiment consists of a series tests on a process where changes are made to its input variables or parameters all at the same time so that one can observe, identify and isolate the variables and their interactions that causes the changes in the output response. In traditional experimentation, experimenters have to change the variables one factor at a time (with all other factors constant) to find the variables that contributes to the response the most. The product considered for improvement is a new surface roughness analyser. The step by step design aspect of this surface roughness analyser is discussed. It offers a new noncontact optical method based on light diffraction principles. When applied to engineering surfaces, the analyser rapidly provides precision surface roughness data on engineering and machined surfaces. The roughness measurement conventionally involves the use of a stylus device, which is drawn over the sample to detect and record variations in surface irregularities.

Case Study of Robust Design of a Measuring Instrument

A laser- and microcomputer-based vision system measures the roughness of the intensity of the collimated, monochromatic light source diffracted in the spectral direction and captured by a video system. This system provides an analog signal to a digitizing system that converts the information, which is subsequently modified to display the surface roughness value. As shown in Figure 2 the intensity is measured as a function of the gray level of the image, is processed by the digitizing circuit, and is compared to a previously defined calibration standard. The system's microcomputer base provides allows the operator to interact in the form of menu-driven steps that provide guidance through the requirements of each phase of the process: the calibration, measurement, and analysis phases.

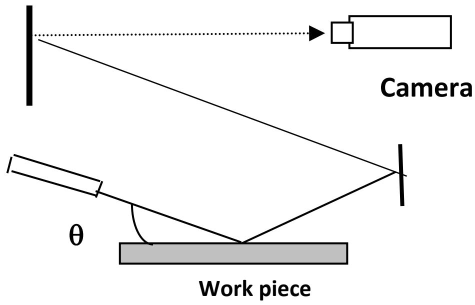

Figure 2. Schematic of the Laser-Based Roughness Analyser

Improvement using robust design: The objective of the robust design study is to find the optimum recommended factor setting for the surface roughness analyzer to minimize the variability in the readings. This instrument relies on the spread of the laser light on the work piece to determine surface roughness; therefore, the analyser's reliability depends primarily on everything involved with the laser and its path. The parameter setting for the new experiment is shown in **Table 1.**

Table 1. Parameter Settings for Surface Analyser

Parameter	Abbreviation	Level 1	Level 2
Laser angle		20°	30°
Background surface	Bs	Glossy	Non-glossy
Distance from laser to work piece	Dt	4.5 in	5.5 in
Background lighting	Bl	off	on

Parameter optimization: Experiments are performed to minimize the effects of the laser angle and the distance from the laser to the work piece and the interactions between them. The parameter setting for this experiment is identified.

Sustainability by Online Measurement and Continuous Feedback: Many industries successfully use the robust design method to determine a system's optimum setting. The application of the method in electronics, automotive products, and photography, for example, has been an important factor in the rapid industrial growth. It is useful and easy to implement in the design process. There are a minimum number of parts to achieve this function since the laser can scan over the work piece, substituting functionality in place of additional parts.

Additional robustness comes from the adaptation of surface roughness analyser for online measurement of surface finish. The online results are compared with the theoretical predetermined set values. Using this data, the hardware parameters are automatically changed to maintain surface finish values on a continuous basis providing online sustainability.

Table 2. Optimal Settings for the Surface Analyser

Parameter	Condition
Laser angle	25°
Distance from laser to work piece	4.5 in
Background surface	Nonglossy
Background lighting	Off

2. Sustainability By Maintaining Service Quality

This methodology examines sustainability in products where customer service is the main goal. The research identifies the most influential drivers of service quality in the elevator industry with the ultimate goal of creating a tool that allows the supply chain to simulate changes in the supply chain and to identify their effect(s) on service rate. This real life experimental study examines an approach to monitoring the service quality of general elevators using root cause analysis (RCA). The example highlights the importance of recognizing structural changes in the value stream that will have the greatest impact on service quality. Original manufacturers could use the information recommended here to demonstrate to customers the benefits of proper maintenance and the disadvantages of insufficient maintenance.

A design challenge for elevator companies is to integrate the many components and subsystems within elevators to produce the most cost-efficient and reliable product. The scenario in the elevator industry shows that elevator companies may choose to produce some components and outsource others. In most cases, the elevator industry provides the following functions to qualified customers:

- Installing new equipment
- Modernizing existing elevators
- Outsourcing the service aspects to supply chain and qualified customers.
- Providing repairs or upgrades

Table 3. Elevator Subsystem Maintenance and Repair Functions

Elevator Sub-systems		**Maintenance Functions**	**Repair Functions**
Mechanical	Fluid power	Lubricate	Use seals, cylinders, control valve, piping
	Frame of elevator carriage	Lubricate sliding guide, roller guide bearing	Lubricate roller guides, limit switch actuation mechanism such as cams
	Rail brackets	N/A	
	Mechanism for hoisting	Lubricate	Inspect drive sheave, liner, gearbox, motor brushes, contact points and isolation pads
	Material for Hoistway	N/A	Limit switches
	Counterweight	Lubricate sliding guide, roller guide bearing	Ensure 2:1 sheave counterweight safeties
	Over speed governor	Control speed	Replace governor, rope, switches, tripping mechanism
	Suspension	Lubricate ropes	Replace ropes
	Critical components and contact devices	Lubricate pivot points	Replace knurled rollers, worn pads
Electrical	Motion controller	Clean relay contacts	Check connectors, dynamic braking resistors, wiring harnesses
	Operation controller	Clean relay contacts	N/A
	Actuator drive	Clean contacts on relays or other high-current capacity components	Inspect dynamic braking resistors, SCRs
	Hoist-way wiring	N/A	N/A
	Traveling cable	N/A	Replace traveling cable
Both	Carriage and doors	Adjust door rollers, lubricate pivot points for linkage-driven operators	Replace operator motor, brushes, or closer
	Position reference system	Clean magnets, lubricate pivot points	Replace magnets, switches, cams
	Car operating panel	N/A	Replace buttons, circuit boards, wiring harnesses
	Exit/Entrance buttons	N/A	Replace buttons, circuit boards, wiring harnesses

The basic functional codes for an elevator system are governed by elevator standards such as, (ANSY 17.1) Their purpose is to ensure that a product is the reliable and meets riders' safety expectations. The value of reliability and maintenance is relative to the environment in which it is installed and its location and height.

The RCA process in this case study examines action items that can be used to resolve the root cause of declining service rate and profitability. Service rate is the average number of service hours spent maintaining or repairing an elevator.

An RCA tool could be employed to help identify the root cause of the issues that negatively affect the service rate of elevators. Because of the very large number of possible causes that can affect an elevator's service rate, this tool helps to focus decision making on factors that significantly affect service rate. (Table 3) This tool will prioritize problems related to service, product, component, part quality, and reliability according to market analysis. Problems with supplier quality and delivery problems can be addressed along with shortfalls in business goals (*related to revenue growth, inventory, customer and employee satisfaction, and health and safety).*

ROOT CAUSE ANALYSIS

Step 1. Identify Customer Requirements by Using an SIPOC Diagram

SIPOC is a type of process map created in six sigma projects to identify the primary elements of a process. A SIPOC diagram is a tool that identifies all relevant elements of a process improvement project before work begins. It helps define a complex project that may not be well scoped, and is typically employed at the early stage of six sigma implementation. The stages of six sigma implementation are: define measure, analyse, improve and control. The SIPOC tool is particularly useful when it is not clear:

- Who supplies inputs to the process?
- What specifications are placed on the inputs?
- Who are the true customers of the process?
- What are the requirements of the customers?

The tool name prompts the team to consider the suppliers of your process (S), the inputs to the process (I); the process the team is improving (P), the outputs of the process (O), and the customers that receive the process outputs (C). The map identifies every relevant element of a process and refines the scope of complex projects.

Step 2. Make a Fishbone Diagram

Figure 5 is the result of a completed Fishbone diagram for the problem of "Service Quality & Profitability are decreasing". A group of process stakeholders are quarried for potential root causes. The objective is to list all of the possible root causes of the problem, when taking into account the many different perspectives of all the process stakeholders.

Step 3. Organize Results

After confirming all possible root causes, they are arranged as: Customer, Systems, Communication, Process, Resources/Material/People and Training. Based on this information, it is possible to come to many conclusions. The research by Morrison and Shetty identifies a method known as Elevator Condition Index (ECI). ECI allows efficient measurement & communication of the current condition of a customer's elevator. Based on the available up-front information on the reliability of the original equipment and projected average life cycles of components, proper maintenance intervals can be identified and recommended. This case study uses an SIPOC worksheet **to** identify the requirements of customers in a value stream and those processes and stakeholders that facilitate meeting third requirements. Important customers and their requirements are clearly identified and quantified. Customer surveys can be used for SIPOC data, but in their absence, business financial performance or other indirect customer feedback can be used to assist in building the SIPOC.

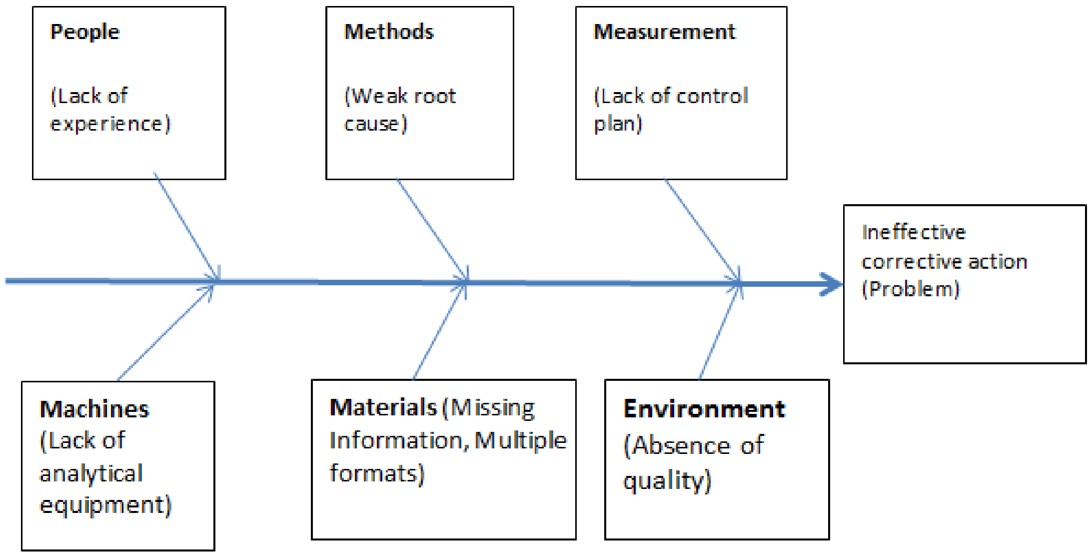

Figure 4. General Fishbone Diagram

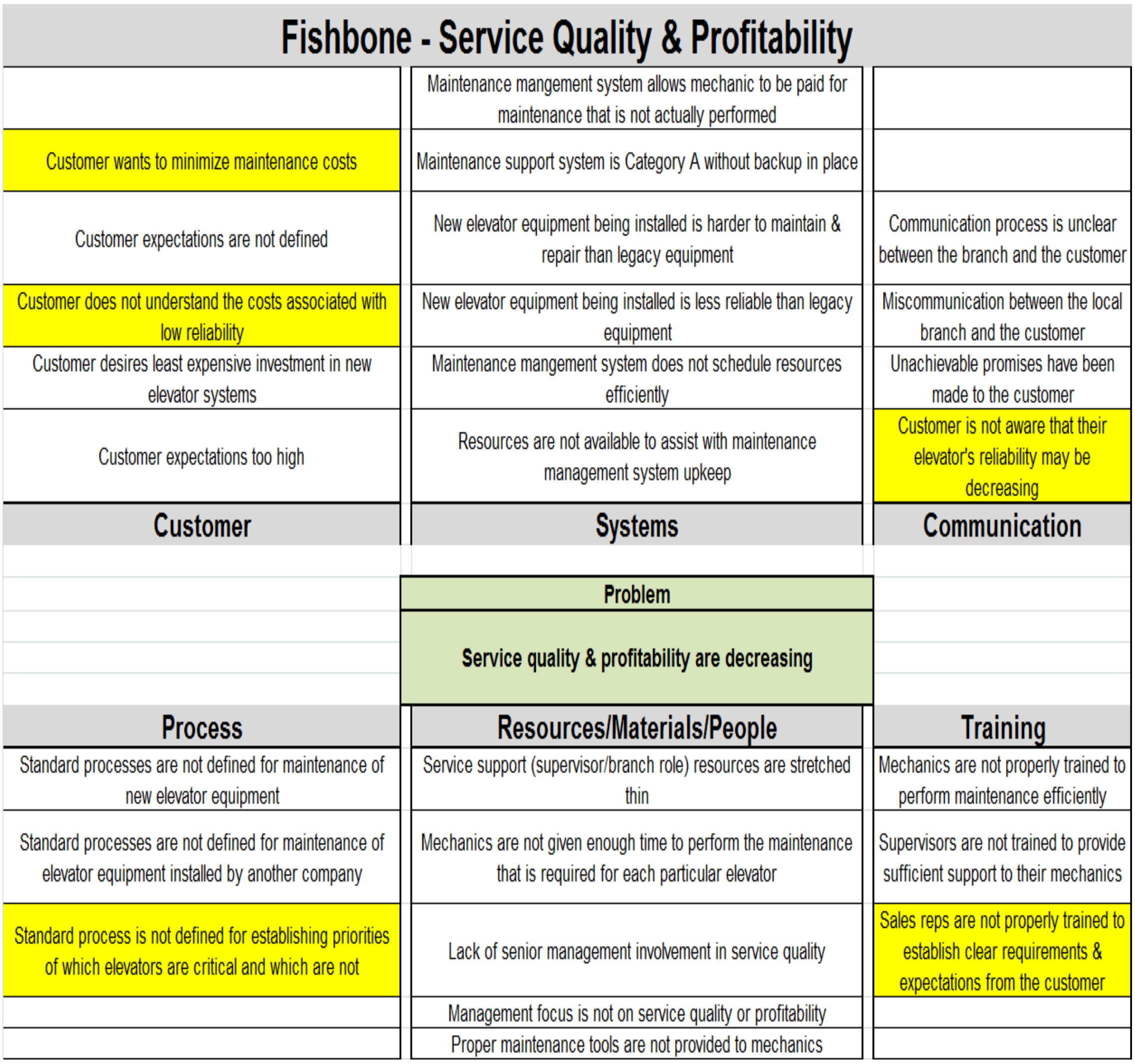

Figure 5: Fishbone Analysis–Service Quality and Profitability

The root cause investigation identifies many significant factors contributing to any decrease in service quality and profitability. The preferred strategy focuses on root causes that will have the greatest impact with the least amount of resources invested. Use of the root cause method helps to identify critical priorities, standard process, status of training, the customer awareness on reliability.

Elevator Condition Index (Eci-Morrison and Shetty)

A more efficient system for maintaining elevators based on their current condition could be implemented using ECI. Data collection and processing is key to driving this advanced maintenance model. A wide array of data is required in order to drive the model, referred to as the Elevator Condition Index (ECI). The ECI of a brand new elevator that is specified within its operational limits for the application, manufactured per the design and installed correctly is defined as 100%. In the real world, there are variables that exist in the design, specification, manufacturing and installation of an elevator, and it may be difficult achieve an ECI of 100%. ECI is calculated based on original equipment reliability, projected average life cycle of key wear components, number of run cycles since maintenance was last performed on each component, cost of emergency repair (parts and labour at local rate) vs. cost of maintenance vs. likelihood of failure. One of the key drivers towards implementing such a maintenance protocol would be the desire for the corporation to capitalize on this information. Profit could be increased by implementing an ECI-based maintenance model in several ways:

1. Charging the customer a specific rate for maintenance based on their elevators' specific ECI, as an alternative to flat-rate maintenance fees. It is expected that the corporation would likely see higher signup rates from elevators with a better ECI, as the maintenance pricing should decrease as a result
2. This will result in preventive maintenance as the problems are fixed before the breakdown. This has the potential for increase in customer satisfaction.

Table 4 SIPOC for Elevator Maintenance (Supply Input, Process, Output and Customer)

Suppliers	Inputs		Process	Outputs				Customer	Impact (1 -10)*
	Description	*Quantified measure*		*Description*	*Quantified measure Delivery*	*Quantified measure Quality*	*Quantified measure Cost*		
Mechanic	Work schedule	Supplied accurately & before the start of the work week	Perform maintenance	System or component level maintenance performed	Per contract schedule (varies based on individual contract)	Components renewed	Maintenance performed within the time allotted by the contract	Building management, building tenants	8
Maintenance management system	Maintenance contract	Contract complete & accurate	Create efficient maintenance schedule	Schedule of all mechanics based on contract commitments	Provided before the start of the work week	Schedule provides for most efficient use of mechanic resources	Travel time is minimized between jobs	Mechanic	9
Supervisor	Maintenance schedule	Provided before the beginning of the work week	Support mechanics, resolve conflicts	Resolve conflicts, provide required tools/materials to complete the job	Resolve any scheduling conflicts or lack of resources within 15 minutes	Correct tools & parts provided 100% of the time	Mechanic downtime (waste) minimized	Mechanic	7
Customer	Desired equipment reliability	% downtime acceptable	Provide definition of acceptable downtime (service rate)	Specific information about which elevators are critical and which are not	Information supplied during contract negotiation	Critical elevators identified correctly	Maintenance is performed on those elevators which are most critical more often & with higher priority than less-critical elevators	Sales rep	9
Sales rep	Basic information on elevator equipment in question	Information is complete & accurate	Communicate with customer during/after contract negotiation	Customer requirements & branch commitments are in-line	Before start of maintenance contract, during update of maintenance contract	Customer requirements are clearly communicated to supervisor, maintenance program is created to meet/exceed customer expectations	Information is provided to branch supervisor in a complete/accurate manner at the start of the maintenance contract or immediately following any change in customer requirements	Supervisor	8

The Elevator Condition Index methodology is a useful tool for addressing the root cause of problems not only in elevator industry but in any industry. It allows for drawing the most appropriate conclusions based on available resources, business and technical requirements. Targeted actions can be taken based on the results of this type of study, so that resources expended will have the greatest benefits. The understanding of robust design, design of experiments and sustainability are critical requirements for a product designer. These concepts, if introduced in the early design courses will provide a solid foundation to engineering students irrespective for the field of study. It can also be a regular topic of research for graduate students. The case studies presented in this paper can be used as real-life examples in the class. The manufacturing industry, invariably have real problems related to robust design.

CONCLUSIONS

The paper examines systems for representing sustainable product design and development. Sustainable product design by robust design and sustainable design by quality of service are two approaches that are investigated with case studies. A case study on a laser based measuring instrument is chosen to support the theory of sustainable product design by robust design. To support the theory of sustainability by quality of service, a case study examines elevator design and maintenance and recommends a new procedure based on Elevator Condition Index. Sustainable design and manufacturing is possible if we deploy the virtual engineering tools to monitor and service manufacturing machinery so that the sustainable benefits are maintained throughout the product design cycle. The sustainability in product development is not complete without examining the choice of a workplace structure of a product.

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