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N Premchand Mahalik

California State University, nmahalik@csufresno.edu

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Green Strategy in Automation and Control Devices and Systems

Nitaigour Premchand Mahalik¹

Department of Industrial Technology, Jordan College of Agricultural Sciences and Technology, California State University,
Fresno, USA. Email: nmahalik@csufresno.edu

Abstract: The extension of Life Cycle Assessment (LCA) is possible in automation and control devices and systems. This paper review introduction to life cycle data acquisition (LCDA) scheme, an idea that can be technology transferred to automation and control field. The scheme is implemented at the device as well as system level. Exemplar platforms that are chosen for experimentation again are sensors, actuators, a process control system and autonomous machine system such as guided vehicle and the life or operational data were recorded. This paper is the extension of the previous presentations. The life-cycle data variables called data objects and related terms are used in order to maintain consistency. However, the way they are interfaced with the devices and systems are considered optimal. That is, in this research the data objects are firmwareed in order to deal with real-time constraints. This attempt in implementation through new tools and design strategy is a new methodology and the results obtained through such procedure are new. It is convincing that the LCDA scheme can improve sustainability, availability, reliability as well as safety of the automation and control systems. Moreover, the LCDA scheme can support LCA attributes such as Design for Environment (DfE) facilitating the emerging green technology and systems. It is also expected that recording of life cycle data can assist in the design of new generation of the devices used in the automation and control applications.

Key words: Life Cycle Assessment, Automated Systems, Product Sustainability, DfE

I. Introduction

LCDA idea was first originated by a research group working in Mechatronics Research Group in the De Montfort University (Moore, et. al, 2000; Simon, M, 1994; Simon, M. et al., 2000). Emerging trends such as sustainability, recyclability, re-manufacturing, re-use etc. as shown in Figure 1 are no more restricted to materials science discipline. They are being applied in product manufacturing establishments (Mahalik, 2008). Sustainability is becoming a decision-making method for the purpose of maintenance of the product that is damaged by environmental and operational impacts (EOI). Recyclability and re-manufacturing works based on the fact where the needs of the present are met without compromising the needs of future versions. The scope of these ideas conventionally falls under the domain of Life Cycle Assessment (LCA): a process that evaluates the EOI that is associated with a product. A product can be a small gadget, a large scale machine, or a process. In a generalized sense, the LCA identifies as well as

quantifies energy and materials that are used in the past and determines how much of recovery is possible and how much wastes have been released to the environment. United Nations Environment Program considers “*Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. LCA provides an adequate instrument for environmental decision support. Reliable LCA performance is crucial to achieve a life-cycle economy. The International Organisation for Standardisation (ISO), a world-wide federation of national standards bodies, has standardised this framework within the series ISO 14040 on LCA.*” (unep.org, 2014). Thus, it assesses opportunities to predict environmental improvements (Zhiqian, 2010). The assessment includes the life cycle of the product and its process activity. It also encompasses extraction attributes of raw materials, manufacturing, transportation and distribution, use, re-use, maintenance, recycling, and final disposal. Incorporating life cycle concepts into the design of products is a three step process: (1) identification of environmental burdens and an inventory preparation. The inventory would encompass materials to be used, wastes to be generated, and emissions released and energy expended over the life cycle of a product or system; (2) establishment of relative environmental impacts

of each of the element; and (3) assessment procedure for prediction. That is, once the current features of the product or system are assessed, improvements can be identified and evaluated. The LCA principle is simply a step forward to Design for Environment (DfE). The DfE workgroups around the world whether regional, national, or international have identified several research areas that support the development of tools for assessing and improving

the environmental performance of products and systems. Three research areas are considered to be of prime importance: (i) inventory data and data assessments, (ii) data and models for impact assessment, and (iii) design tools for improving environmental performance (Weidema, 2000).

Figure 1: LCA (Recycle, re-use, remanufacture scheme)

LCA scheme has been considered in the electronic products manufacturing industries. The electronics and electrical waste are dumped because of problematic recycling process. Many companies estimate that they can save a significant percentage of manufacturing cost if the products are recycled. For example, Xerox had estimated that a sum of \$500 million a year would be saved if the photocopier components are re-used (Xerox Corporation, 1996). In 2000, the objective of Eureka project called CARE (Comprehensive Approach for the Recycling of Electronics) Vision was to develop a method and procedure to recycle electronics waste. Bearing in mind that manufacturing and processing constitute significant economic component, it also contributes to greatest potential impact on the environment. The sustainability and recyclability idea can be applied within the automation and control products and systems. Because the automation and control products or machines are built with the basic control components or devices such as sensors and actuators, it is perceived that a systematic approach can be developed to accommodate the LCA idea. LCA vision can then be extended into the machine control systems or automated system in general. The goal is to achieve re-cycling and sustainability. To attain goals of sustainability and re-cycling of the devices or machines the need for novelty and creativity in solving technical problems within the automated system area needs to be advocated (Mahalik and Kim, 2005). The two important reasons for this paradigm shift can be attributable to (i) products and machineries within the automated systems are becoming increasingly customized, and (ii) the

consumption of materials and environmental resources to build them is accelerating. The life cycle of these systems can be best understood if the focus is given towards two aspects - the beginning and end of life cycle. Note that the control system integrators have exactly knowledge on when a machine or a control device was installed and operational. However, no information is available about the end of the life cycle. As a matter of fact there has not been any basis of knowing the information on 'environmental impact' on the product or machine. The provision of *life-cycle data* is considered to be an effective way forward in addressing life cycle.

The idea can support the need for recycling, reuse and remanufacture in that materials, products and systems can be preserved for overall sustainability minimizing waste. Life cycle data recording will be a means of analyzing the run-time operational impacts on the devices, components, products and machines. Life cycle data acquisition or recording followed by analysis can help manufacturers to design more sustainable devices, products, and machines with improved performance, quality, reliability, and reduced total life cycle costs while developing the new generation of products (Moore *et. al*, 2000).

II. Green Box System

It was observed that environmental concerns are becoming increasingly important to manufacturers of automation components and machine systems. Recycling is an ideal opportunity to significantly reduce the environmental impacts because major manufacturers are already encountering the environmental challenge. It is a fact that LCA idea has

not yet penetrated the avenue of industrial automation and control systems.

From several standpoints, this section presents justification as well as the need for recording of life cycle in information of the devices, products and systems.

Industrial economy vs. service economy: The industrial economy and service economy are two paradigms. Central to the former lies in the value of exchange in the product that is sold or bought. In the service economy, however, it is the value of utilization, which is apparently a performance driven scenario. As the utilization of the product for the basic interest of the consumer, the producer should also stay with the product to the extent to which it must fulfill satisfaction of the customer. Although, all parts of a product in the end cannot be managed effectively, but the strategy can offer opportunity to upgrade, reuse, and repair the parts, or can at least be recycled most profitably. The service-product approach would provide producers and companies with opportunities to turn possible future take-back obligations to competitive advantages. As a result the value of 'utilization of the product' will be boosted up and overall economy will rise.

Sustainability: The trend towards component and machine sustainability is emerging. Design for disassembly and recycling would reduce environmental impacts at the end of the life.

Therefore, a holistic life-cycle analysis approach should be considered for the entire life of the product. Such analysis can be described as a 'cradle to grave' assessment. The approach can be used to investigate the durability as well as the sustainability including the scrutinizing of dynamic environmental effects. Greater sustainability will make systems more available and affordable for an increasing number of requirements.

An assessment system: LCI recording of automation components and systems will serve as an assessment system because it will be able to make predictions of the future rates of component life usage under various operating regimes and for various damage processes. The scheme should be able to estimate past life usage, based on the actual operating history, and should ideally be capable of utilizing existing design and assessment data so that the requirement for new analyses would be minimized. A life assessment scheme in terms of life cycle data can be designed to perform life usage calculations for specified components, products, and machines. Systems, components and machines fitted with capabilities for self-recording of life-span could make the future information more robust. As mentioned, the focus on the life of a product, device or machine system has been shifting toward after sale support and

take-back of used products. It was observed that the labor cost for repairs and reconditioning often expensive. Knowledge of pattern-of-use using embedded life-cycle data acquisition technique are considered to be an effective way forward in addressing such issues. However, these functions are not supported within current design practices for components or machines (Simon, 1994). An analogy to the concept of recording Life Cycle Information (LCI) can be made with the 'black box' of a flight recorder. The suggested LCI in products and machineries then can be called green box.

III. Methodology

This research seeks to develop knowledge in establishing pattern- of-use for control components and machines to formulate associated life-cycle data acquisition methods. Low cost microprocessor technology and sensing techniques will be used. The focus will be on now life data acquisition and analysis be applied to comparatively less expensive products and machines. Tracking of life-cycle data of the devices, components and machines will facilitate life-cycle analysis and provide life-cycle information. An effective way to introduce the life- cycle information concept into the automated systems is by conducting a series of experiments using a number of components and machines in first place. The experiments will provide experience with life-cycle information concepts and analysis techniques, insight into how life- cycle information can best be tailored to each particular product, system or machine, and the potential benefits and rewards.

Such an ad hoc procedure will provide added advantages such as Evaluation – Since the scheme is new, it has to be evaluated by the use of basic elements; and Validation - The idea is sensitive to the real-time control system environment because another level of processing may degrade the performance rather than improving; Integration – The components and the products are available in the environment but the designer unaware of what should be the life- cycle data. So, it is necessary to know whether the scheme should be an integral part of the control system or it should be a separate layer. So, the life-cycle data should be considered as an important control design characteristic; Results analysis - life-cycle data analysis should produce useful results for decision-making; and Operational flexibility – it is necessary to understand the operational flexibility in first hand. Design controllable factors that significantly affect the life-cycle data maintenance needs to be separated. With our preliminary test based on the above mentioned considerations in mind, we included the specification of requirements for life-cycle data for first time as (i) design independability, (ii) integrated approach, (iii) distributed environment, and (iv) usage of more standardized systems. Furthermore, a components-based approach was adopted for the design of life cycle data

acquisition platform. The devices and components used in systems were made 'autonomous' as well as 'co-operative'. Efforts are made to realize 'interoperability' of devices and components. The life cycle data acquisition and analysis was implemented in two ways; (i) as a general-purpose device which is physically associated with the product or machine but operating independently, and (ii) as an integral part of the machine or system. The approach in this work adopts the latter form as the main intention is to introduce the life-cycle data concept in the control products or systems. We assumed that the sensing, processing and control capabilities are already available within the existing process. Data concerning the life cycle of the component and machine were obtained from the sensing, processing and control devices integral with the system.

IV. Firmware driven Results

The life cycle data acquisition and analysis was implemented in sensors, actuators, and machine system. The results presented in this paper is new compared to earlier results (Mahalik and Kim, 2005; Mahalik and Soak, 2006; Mahalik and Au, 2008) in that the tools and methodology used in this research are advanced and more compatible to the idea. For the recording of life-cycle data we defined several variables under a group called data object class. The same life-cycle data variables called data objects (DO) and the related terms are used in this paper in order to maintain consistency. However, the way they are interfaced with the devices and systems are considered optimal.

That is, in this research the data objects are firmwared in order to deal with real-time constraints. This attempt in implementation through new tools and design strategy is a new methodology and the results obtained through such procedure are new. In the follow up, this section continues reviewing the terminology. It is a name defined for a specific type of data to be recorded from the component and machines. The DOs represent a string of text that holds the life-cycle data called life span index (LSI). These values are used for the analysis of run-time operational impact rather than environmental impact as in case of material science. The DOs are thus definable static objects and their numbers and type vary depending on what type of data would be needed for impact analysis. For instance, consider a pressure sensor as well as a color sensor. Besides the physical part, the electronic units within the pressure sensors are transducers, amplifiers and perhaps an A/D converter. The additional modules within the color sensors are additional electronic circuitry for the illumination of a lamp. Possible definable DOs for both the sensors could be total on duration. Other object could be defined for the color sensor.

As requirement changes new modules or components (and hence the data objects) are added into the component/systems. Comprehensive identification of the

object types within sensor components is not possible. However, the list presented below represents some classes which have been identified in this research study. TOD (Total Operation Duration): How long has the sensor been in active operation; NZD (Normal Zone Duration): During active operation, how long has the sensor component remained in a normal operating zone. (Normal zone can be derived from the manufacturer's data sheet). UTD (Upper Threshold Duration): During active operation how long has the sensor component been above the upper threshold (The threshold value can be obtained from the manufacturer's data sheet); LTD (Lower Threshold Duration): During active operation how long has the sensor component been below the lower threshold. (The threshold value can be obtained from the manufacturer's data sheet); ONF (On and Off cycle): How many times the sensor has been on and off; PSNZD (Power Supply Normal Zone Duration): How long has the sensor's power supply value been within normal conditions of operation; PSUTD (Power Supply Upper Threshold Duration): How long period the sensor's power supply was beyond normal operating value; PSLTD (Power Supply Lower Threshold Duration): How long has the sensor's power supply been below the normal operating value; CSVM-1 to CSVM-5 (Count Sensor Validation Mode-1 to SVM-5): How many times have the SVMs appeared during run-time.

IV.I LSV

LSV is defined as a predictable value given by the device manufacturers or control system designer. LSVs are the *measure* of active life of the data object. The LSV is a new idea in the context of life-cycle data. The initial values can be assigned either by 1) observing the performance of the sensor in past or 2) proving a most suitable number at the design stage. For example, let the LSV of UTD (Upper threshold Duration) of the sensor is 1000 hours. That means, in first place it is assumed that the sensor can operate safely 1000 hours without any expected damage to it. Once the LSV has been consumed, the sensor can be replaced or recycled. So LSV of the life-cycle data objects play significant role in implementing LCDA scheme. However, judging its value is crucial in first place.

IV.II. Requirements

The life-cycle data for the sensor component was evaluated. A humidity sensor was used for this purpose. The code was written in the Neuron C language. NetInstall was used to install the sensor component into an automated system. The Neuron-C variables used to represent thirteen objects are shown in the table below. The variable begins with LC (Life_Cycle data). *Sr* stands for sensor and *H1* stands for Humidity Sensor-1 (Figure 2). LSV corresponding to life-cycle data objects of the sensor component are also shown. Tables show observations three months and six months after installation, respectively.

The life-cycle data objects for pneumatic actuator systems were seen overwhelmingly high. Each and every aspect of physical and electrical behavior can be taken into account: threshold vibration amplitude, threshold chamber

temperature, frictional force, number of power on and off cycles, total strokes elapsed, and so on. These are useful information to record for the purpose of maintenance, repair, recycling and re-manufacture.

Table 1: (a) DOs of sensor; (b) LSV in 6 months

LCDADO	Variable Names in Neuron C	Life Span Value
TOD	LC_Sr_H1_tod	10,000 hours
NZD	LC_Sr_H1_nzd	10,000 hours
UTD	LC_Sr_H1_utd	10 hours
LTD	LC_Sr_H1_ltd	100 hours
PSNZD	LC_Sr_H1_psnzd	10,000 hours
PSUTD	LC_Sr_H1_psutd	10 hours
PSLTD	LC_Sr_H1_psltd	100 hours
ONF	LC_Sr_H1_onf	1000 times
CSVM-1	LC_Sr_H1_CSVM-1	50 times
CSVM-2	LC_Sr_H1_CSVM-2	50 times
CSVM-3	LC_Sr_H1_CSVM-3	1 times
CSVM-4	LC_Sr_H1_CSVM-4	10 times
CSVM-5	LC_Sr_H1_CSVM-5	1 times

The work relating to pneumatic actuator systems involved recording of the following objects. *TPSC*: Total piston stroke cycles; *PSONF*: Power on/off times (valve); *AVM-1*, *AVM-2*, *AVM-3*, *AVM-4*: What kind of AVM (Actuator Validation Mode) occurred and how many times. Other data objects such as (1) how many times the vibration amplitude has reached the threshold value, (2) how many times the chamber temperature has reached the threshold limit etc., mentioned above, can also easily be recorded. This needs additional interfacing and sensory devices. The design and experimental bench used for the evaluation of actuator validation, was also used to evaluate the life-cycle data scheme. Here, only the application code which is responsible for recording life-cycle data objects was changed. The tests were carried out several times. Figure 3 illustrates a specific test result. The front end was designed using object server and Visual Basic. The lengths of the horizontal bars illustrated in the above window define the Life Span Value (LSV) of the respective objects defined for the actuator. As the name suggests, LSVs are the *measure* of active life of the data object. The portion in black color along the horizontal bar conveys the information to the user about the consumption of the LSV. In a typical example the LSV of the actuator's piston cycle may be 10,000 or more. The LSV is a new idea in the context of life-cycle data. The initial values can be assigned either 1) based on past performance of actuator, or 2) by assigning a suitable value at the design stage. For example, let the LSV of the actuator's piston cycle be 10,000.

That means, in first place it is assumed that the piston can operate 10,000 times safely without any expected damage to it. Once the LSV has been covered the system can be checked, replaced or recycled. If the piston is perfect (i.e., it was found that no damage or harm has

happened to the piston after 10,000 times in operation),

LCDADO	After three months	After six months
TOD	2631 Hours	4918 Hours
NZD	2006 Hours	4223 Hours
UTD	503 Hours	538 Hours
LTD	121 Hours	157 Hours
PSNZD	2603 Hours	4883 Hours
PSUTD	3 Hours	4 Hours
PSLTD	26 Hours	32 Hours
ONF	37 times	46 times
CSVM-1	2 times	2 times
CSVM-2	0 times	0 times
CSVM-3	0 times	0 times
CSVM-4	0 times	1 times
CSVM-5	0 times	0 times

then the current LSV can be increased to a value more than 10,000 while designing the new version of the actuator (piston). On the other hand, if the actuator was found to be damaged then the LSV must be decreased to a new value and the design and construction of the actuator modified accordingly. As such LSV of the life-cycle data objects play a significant role in implementing the life-cycle data scheme. However, judging the LSV value is crucial. It can also be noted that LCDADO vary from actuator to actuator. For example, LCDADOs for an electric motor may be very different from those of a pneumatic actuator. In this study six data objects were defined and their LSV are shown in the table above (Table 2). The following snapshot illustrates (Figure 4) recorded LCDADO for the conveyor-based material handling systems at an instant during operation. The length of the horizontal bar represents the LSVs of the respective data objects. The portion in black color along the horizontal bar conveys the information to the user about the consumption of the LSV. The LSV is absolutely a new idea. The initial values can be assigned either by (i) observing the performance of the component/system in past or (ii) providing a most suitable value at the commissioning stage. Within the window, LEVELs of the Certainty Values (CVs) of the Validation Modes of the temperature sensor were also displayed. Adverse symptoms were introduced into the sensors, actuators and switches to observe the corresponding validation modes. Components-based approach was adopted. Meaning, life-cycle data scheme and algorithm was implemented at the device or component level (Mahalik and Soak, 2006). Components based approach exhibits the key attributes, namely; autonomy, co-cooperativeness, configurability, flexibility, integratability and scalability. Autonomy was achieved by providing the devices with the functional resources. Flexibility within the application relates to the degree

with which the application could accommodate changes in functional requirements. Integrate ability within the material handling system were achieved by allowing the components to group and control the system and scalability was achieved by using configurable platforms and tools. The ease of communications between the components allows the control network to be used to provide a flexible integrated system. Instead of each component acting as a standalone item the whole system can be treated as one system. At the macroscopic level the machine control components work together to achieve efficient global control. At the microscopic level the component performs local validation and control on devices.

This level of integration is provided by a high level of system assessment being incorporated into each component within the system in the form of a distributed scheduling mechanism. The flexible mechanism assists smooth flow of products thus improving process synchronization. This work also attempts to identify LCDADOs of another automated system such as mobile robot – semi autonomous vehicle (SAV). It was convinced that the life cycle data scheme within the SAV would be a potential value while considering the sustainability and re- manufacturing aspects in to account. In this machine life cycle date scheme can be implemented to record (i) The number of power-on cycles, (ii) Number of revolution the motors (there are two electric dc motors with the SAV; one is employed to drive the wheel and another is employed to drive the steering) has elapsed/or motor running hours, (iii) Temperature of operation at appropriate place, (iv) The vibration level at the appropriate place, (v) Battery charging and discharging times, (vi) Number of times accident occurred (due to obstacles), (vii) How many times the indicating lamps were on-off, (viii) What kind of faults occurred in the devices (motors, indicating lamps etc.) during operation etc. etc., (ix) The number of revolutions the wheels have made, (x) Engagement time of the vehicle, (xi) Total distance covered, (xiii) Total load already transported, (xiv) Power consumption rate, (xv) Total power consumed, (xvi) Normal/Upper/Lower speed duration etc.

Figure 2: Consumed LSV; Figure 3: Consumed LSV typical pneumatic actuator

Table 2: LCDADOs of pneumatic actuator; Figure 4: System-level life-cycle data scheme

Component	LCDATA DO	Life Span Values
System		
Switch-1	ONF: On Off Cycles	10, 000 times
Switch-2(a)	ONF-2(a)	10, 000 times
Switch-2(c)	ONF-2(c)	10, 000 times
Switch-2(c)	ONF-2(c)	10, 000 times
Motor	TOD: Total Operating Duration	75, 000 hours
	NZD: Normal Zone Duration (nominal speed)	75, 000 hours
	UTD: Upper Threshold duration (above nominal speed)	100 hours
	LTD: Lower Threshold Duration (below nominal speed)	500 hours
	ONF: On Off Cycle	10, 000 times
	PSNZD: Power Supply NZD	75, 000 hours
	PSUTD: Power Supply UTD	100 hours
	PSLTD: Power Supply LTD	500 hours
	TR: Total Revolution	4.5 * 10E9 hours
	CAVM-1: Count Actuator Validation Mode-1 (AVM-1)	10 times
	CAVM-5: Count AVM5	10 times
	CAVM-6: Count AVM6	10 times
Robot	RET: Robot engagement time	75, 000 hours
	TPPO: Total Pick and place operation	10, 000 times
Colour Sensor	ONF	10, 000 times
	PSNZD	10, 000 hours
	PSUTD	50 hours
	PSLTD	100 hours
	LONF	500 revs.
Conveyor	CR: Conveyor Rotation	10, 000 revs.

V. Discussion and Conclusions

Life Cycle Assessment (LCA) is a method to assess the environmental impacts of a product, process or activity throughout its life cycle from the extraction of raw materials through to processing, transport, use and disposal (Weidema, 2000). Consumer pressure, legislation, standards, the need to maintain competitive advantage or the desire to be a good corporate citizen has forced designers and manufacturers to consider the environmental impact of their products. This led the manufacturers to incorporate environment as a parameter in the development of new products. The literature searches in LCA of materials and consumer products (Lieferrig, et al, 2010) was the trigger to consider similar concepts in relation to control components, products and machines within automated systems to achieve desired features such as design for environment, desire to be good corporate citizen, competitive advantage, sustainable component and machines, advances in the design of smart components, products, and machines. Work undertaken was to extend LCA concepts into the domain of automation components and machines in terms of realizing Life Cycle Data. Life cycle data has been defined as a scheme for systematically recording and assessing life-cycle information associated with the product, component, and machine over its entire life. Life cycle data can be considered as a valuable decision support scheme for both the product manufacturer and end users. Life cycle data includes acquisition of relevant 'life-cycle' data from the products during their operation (consumption) so as to enable the manufacturer or producer to analyze and to take effective decision whether or not to re-use, re-cycle or recover the product. Life cycle data suggests that, life-cycle data would be used to locate the key environmental issues that have to be addressed in the redesign process and thus establishes acceptable life-cycle data requirements and decision criteria. At the end of life, during the analysis process, the recorded life cycle data are used as the indicator, which enables the producer to get a better understanding of the environment of the product during its life-cycle. The results are used to set priorities in the design process and to focus on the issues that offer the best opportunity for improvement. The underlying factors encouraging the viability and significance of life cycle data can be attributable to optimization of existing products by identification of weak points, development of new products after analyzing weak points, performance comparison with alternative products, optimization of waste treatment scenario, and supplying information on the environmental friendliness of product development of new life-cycle criteria that have to be generic and device, components, product, and machine independent (Mahalik, 2005; Herath et. al, 2012).

There are several beneficiaries of green box technology because life cycle data acquisition schemes can offer added advantages in terms of product development,

design for environment, longer utilization of components or devices used in the products, component and machine evolution, and eventually energy and materials savings – altogether can be under one banner, sustainability.

In automation and control domain smart products are those that have online or real-time diagnostic features. One of the performance measure criterions are the level of fault tolerant capability of the device and system. While sensors and actuators are designed with self-diagnostic features, machine systems are designed with self-monitoring capability. Self- diagnostics and self-monitoring performance indices are for run- time attributes and traditionally, they are referred to as smart devices or systems. The scope of smartness can be extended by embedding additional attributes that is suggested in this research as green box attributes. Smart products and components are those then will include features that allow the product itself to collect or carry information about its life cycle. The idea of adding features to products which record life-cycle data is defined here as the smart product.

Manufacturers do not know about the pattern of use of the products because of two reasons: once the domestic appliances are sold they usually never seen again, and the green box idea or recording of life cycle information is new. When a product will come back either under guarantee, for service or at end-of-life for possible recycling or re-manufacture it is necessary to know its life history. Smart product design thinking can lead to the need for data on the use stage of the life cycle. The implementation scenario is not just for environmental reasons but relevant to performance, reliability and durability. Industrial exploitation of life-cycle data acquisition methods will undoubtedly lead to higher quality and reliability in products, lower life cycle costs and better understanding of patterns of customer use as well as higher environmental quality, since products can be designed for whole life with confidence. Benefits through the provision of life cycle data acquisition implementation in the devices and systems can be extended to large systems developed by the manufacturers and distributed by the suppliers, through improved after-sales support, maintenance, repair and take-back of end-of-life products. Life cycle data acquisition may lead to the birth of a potential market for even electronic products and modules.

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