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An overview on the obsolescence of physical assets for the defence facing the challenges of industry 4.0 and the new operating environments

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ABSTRACT: This contribution is intended to observe special features presented in physical assets for defence. Particularly, the management of defence assets has to consider not only the reliability, availability, maintainability and other factors frequently used in asset management. On the contrary, such systems should also take into account their adaptation to changing operating environments as well as their capability to changes on the technological context. This study approaches to the current real situation where, due to the diversity of conflicts in our international context, the same type of defence systems must be able to provide services under different boundary conditions in different areas of the globe. At the same time, new concepts from the Industry 4.0 provide quick changes that should be considered along the life cycle of a defence asset. As a finding or consequence, these variations in operating conditions and in technology may accelerate asset degradation by modifying its reliability, its up-to-date status and, in general terms, its end-of-life estimation, depending of course on a diversity of factors. This accelerated deterioration of the asset is often known as "obsolescence" and its implications are often evaluated (when possible), in terms of costs from different natures. The originality of this contribution is the introduction of a discussion on how a proper analysis may help to reduce errors and mistakes in the decision-making process regarding the suitability or not of repairing, replacing, or modernizing the asset or system under study. In other words, the obsolescence analysis, from a reliability and technological point of view, could be used to determine the conservation or not of a specific asset fleet, in order to understand the effects of operational and technology factors variation over the functionality and life cycle cost of physical assets for defence.

1 INTRODUCTION

Throughout history, technological advances have always been applied in armed conflicts to allow certain superiority against the enemy. Such conflicts have served in many cases as fields of experimentation to validate progress that, subsequently, have had their application in the civilian world and vice versa. Identically, today's conflicts apply technology, where the digital transformation becomes more and more present. In fact, there is a historical constant where the same means used to create wealth, are those used for warfare, and vice versa [1]. I.e., there are dual-use technologies, so that the developments and commercial innovations take advantage to the military sector and vice versa. To this fact, it must be added that enemies can also have these high-tech devices easily.

Many functions from gadgets that emerged before, keep its purpose now, adapting them to the new circumstances, both operational and technological. In the case for example of an armoured vehicle, the basic characteristics that emerged during the First World War (protection, mobility and firepower), are the same that are expected currently, though, with the own technological advances of today. These basic functions are seen nowadays in continuous development and improvement according to the new technologies that are emerging to meet specific operational needs. To such functions it is added now a fundamental property as the reliability of the systems themselves, as well as other concepts such as availability, maintainability and safety. This contribution deals with these technical characteristics from the standpoint of a military asset, introducing terms such as obsolescence and useful life of these systems, and also relating the effect on these assets and their characteristics of new technological tools included under the concept of industry 4.0.

2 CONCEPTS OF ASSET MANAGEMENT AND ITS ADAPTATION TO THE CASE OF DEFENSE

2.1 *RAMS parameters of an asset and its life cycle cost*

Reliability, availability and maintainability are parameters used in assets management whose analysis is usually known by the acronym in English of RAM. Frequently, it is added the S of security and/or safety, although some authors referenced it as sustainability, and hence the acronym results as "RAMS analysis".

- Reliability: capacity of the system not to fail, i.e., the probability that the system complies with what is expected of it
- Availability: proportion of time that the asset is useful to be used (in principle, it does not have to be operational, although it can be considered also an operational availability of the asset)
- Maintainability: ease of the asset to keep its normal operation, i.e. it would be inversely proportional effort in maintenance activities
- Safety/security: features set of measures that are taken to avoid and prevent accidents, or protect from illegal activities

Apart from the a. m. concepts, stricter definitions can be found in the references [2], [3] or [4]. These terms are closely linked to the concept of useful life, which is associated with the time during which the system continues fulfilling its functions [5]. Over the useful life of an asset, it must maintain and keep its value. Each of the stages of the life cycle of an asset will have some associated costs being finally life cycle cost the sum of all these costs. In other words, a life cycle cost analysis must take into account: costs initial acquisition of the physical asset (covering the costs of development and investment); operational costs; maintenance costs (planned, corrective as well as overhauls); and the costs associated with the divestiture of assets or dismantle the installation. If the asset is still used beyond than expected, this latter term, instead of a cost may be considered a Residual value (if for example is sold to a third party). All of the above are often treated from the standpoint of an industrial physical asset, which tend to have a certain operating profiles, to a greater or lesser extent, under controlled environments.

From the perspective of a military asset, they will find themselves under the paradigm of having to deploy to different environments, with changing mission profiles and where logistics is critical to maintain its performance. I.e. when a machine is acquired for a production process, this process can be more or less predictable or stable, while in the case of an asset for defence, it should be added the uncertainty of mission (surveillance, defence, humanitarian support… and other profiles), the conditions of operation that will be used (deserts, icy areas, forest, urban locations...), and of course technological change. Consequently, the estimation of lifespan for an industrial asset does not have to coincide in a military system. This end of life of an asset is known as obsolescence, which can slow down if redesigns and updates throughout the life of the asset are considered.

2.2 *Obsolescence and modernization of an asset*

The term "obsolescence" was used for the first time in relation to basic products [6], [7]. However, it has been employed in the industrial environment [8], [9], relating to functional factors (changes in use), economic (cost of continuing to use it, regard the cost of replacing it with an alternative), technological) efficiency of technology assets, in comparison with the new alternatives available), or social (trends of users, changes in legislation or regulations of health and safety...) [10], [11]. These asset shifts changed its durability and obsolescence [12]. Therefore, there are tangible factors, such as the functional and economic factors more related to the depreciation of the assets, and intangible factors such as technological and social, more subjective or prospects-related to the market [13].

Accordingly, maintenance activities are linked to the functional and economical obsolescence, preserving the value of the asset in a physical sense and combating the economic depreciation of own assets. In this sense, there is a time-dependent relationship between the obsolescence and the analysis based on reliability according to functional and economic factors [14] (life cycle costs). In other words, maintenance should be assessed by comparing the assets value regarding the cost involved in repair or replacement. In this analysis, it may be the case that the decision to repair the asset results in disproportionate expense to preserve the value of the investment [15]. On the other hand, the modernization activities will be more closely linked to combat social and technological obsolescence.

In both cases, an improvement in maintenance and/or the possibilities of a modernization has to go exclusively through direct changes on the asset itself. It can be also related to assure the execution of tasks, training, spare parts and tools distribution, logistics required for the coordination of all aspects etc... allowing the system to be available and in operation as long as possible, maintaining and implementing its performance during its lifetime. I.e. new technologies not only can and must influence improvements on own assets, but also on the integrated logistics support provided to it.

3 INNOVATION IN MILITARY ASSETS

As seen in the previous section, with a view to slowing down the obsolescence of a military asset, it can be considered incorporating modernizations (on the assets and/or on its logistical support) taking advantage of the new technologies that now are at our disposal. It is important to emphasize that these advantages are not only applicable to the own assets, but they can facilitate and improve all those activities that surround system and needs that are essential to keep it in "life". With that intention, it is relevant to deal with the industry 4.0 concept, providing a panoramic view of possible applications in the military assets, focusing on the possibilities in terms of logistic support integrated with a view to improving precisely the reliability, availability, maintainability and safety of assets for the defence.

3.1 *Evolution to the "4.0"*

The origin of the term industry 4.0 refers to the fourth Industrial Revolution, understanding that the first arose when machine steam at the end of the XVIII century, the second when we implemented the use of electricity and manufacture in series in the last third of XIX century, and the third Industrial Revolution to that when automate factories began already in the s. XX century. Today, the fourth Industrial Revolution has to do with the digital transformation applied to the industry in the search for connectivity and operational excellence. It was named for the first time in a study conducted in Germany in 2011: "Smart Manufacturing for the Future", Germany Trade and Invest [16]. Associated with the term industry 4.0 are usually define 9 technologies such as the ones shown in the following table (Table 1).

Apart from these nine technologies, sometimes are added some others such as vehicles or autonomous or unmanned aircraft (drones), new materials (Graphene), artificial intelligence, digital platforms... having their place in the nine

Table 1. Technologies associated with the industry 4.0 concept.

Technology	Description
Robotics and computer vision	• Cooperative and autonomous robots. • Numerous integrated sensors and interfaces standardized.
Additive manufacturing and 3D scanner	• 3D printing, especially for prototypes and spare parts. • Decentralized 3D installations to reduce inventory and transportation distances. • Flexibility of forms, quickly not to use tools, cost savings
Augmented and virtual reality	• Augmented reality for maintenance, logistics and all kinds of operational procedures. • Supporting information display, for example, through smart glasses.
Simulation and modelling	• Simulation of value networks (flows). • Optimization based on data in real time from intelligent systems.
Horizontal and vertical integration	• Integration of data between companies based on standards of data transfer. • Precondition for a fully automated value chain (the company customer, the plant management)
Industrial Internet (IoT. Internet of things)	• Network of products and machines. • Multi-directional communication among objects in the network. • Cyber-physical Systems
Cloud computing	• Management of huge volumes of data in open systems. • Communication in real time for production systems.
Cybersecurity	• Operation in networks and open systems. • High level of networking between machines, products and intelligent systems.
Big data and data analysis	• Complete evaluation of the available data (for example, ERP, SCM, CRM, and data of machine). • Support and optimization in real time for decision-making

mentioned categories. All previous technologies have applications without a doubt in the military sphere. In this sense, one of the first objectives of digitization can be precisely:

- To support the concept of life cycle of military assets.
- Determine the needs of services and infrastructures in the evolution of the means for the defence.
- Study the incorporation of management software mass of data that allow the use of artificial intelligence methods.
- Evaluate trends.
- Get lessons learned.
- Control and manage the asset lifecycle and engineering.

In general, the inclusion of the concept of logistics support 4.0.

I.e. apart from the operational improvements that may benefit the assets themselves, first advantage is that assets management can be improved for the defence in maintenance (corrective action and scheduled inspections), in the management of spare parts and material (supply of spares, tools and consumables in time and place), in the adaptation of systems to operational requirements, control of assets configuration (design modifications) and, in general terms, the determination, evaluation and improvement of support along the life cycle through the support updating capabilities of the army.

3.2 *Technological trend of Defence 4.0*

The first half of the XXI century is characterized as a period of great political, social and ecological changes (translation of the geopolitical focusses, increase of the world population, consumption of large amounts of resources, effects on the biosphere...). All this happens in a highly globalized world and parallel to the highest scientific and technological transformation of history [17]. This context implies complex scenarios with increased uncertainty where the effect of technology cannot be ignored. Recent times correspond to the most technologically advanced in the history of mankind, driven by the digital revolution, but also by biology and nanotechnology [1]. In the digital realm, a growing convergence of cyber, physical and biological domains appear with more complex and higher value-added products and services. Therefore, at conventional operating environment: land, sea and air; it must be added now the virtual or cyber space (Figure 1).

In general terms, it is found an increasingly globalized combat environment more connected and with greater presence of digitized and automated means that (making a comparison with the industry) could be called “Defence 4.0”. All this obliges the armies to a better adaptation to the changes because there are factors that radically transform the character of the war fighting. The Defence sector must therefore nourish of the digital revolution in aspects such as connectivity in real time (internet of things, “low cost” sensing), the collaborative robotic (drones, autonomous vehicles, 3D printing, exoskeletons), the Automation (augmented and virtual reality, artificial intelligence, Big Data, processing in the cloud...).

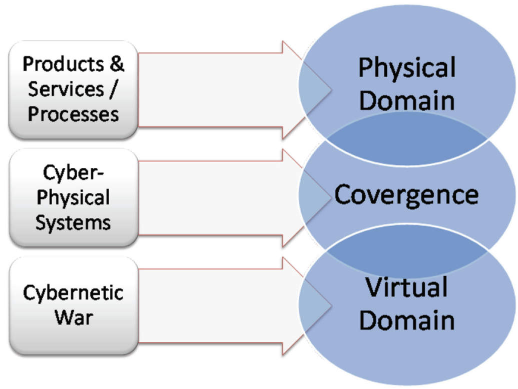

Figure 1. New operational environments.

The application of these technologies must take into account the platform on which it is incorporated (aircraft, vehicles, weapons, general equipment systems...), means for implementation (software, hardware...), as well as logistics and tactical elements (equipment of support, training and simulation systems, digital stands for technical documentation, mission planning systems...) [18].

4 CONCLUSIONS

Today, advances in technology and changes in operation environments oblige the designs of assets for the defence to be flexible and to evolve with the life of the system. In other words, the conservation of a fleet of military assets updated and the fulfilment of operational demands require redesigns and upgrades throughout the life of the items, as well as to streamline everything related to their logistical support. In order to emphasize those scientific issues addressed along this paper, it is relevant to explore the current willingness of industries, together with universities and research centers to collaborate and constitute a kind of community of interest in the area of maintenance [19], logistics support [20] and, in general terms, the integration of technological solutions [21], in order to overcome the problem of obsolescence in the defense sector.

As it has been observed throughout this document, the application of technologies associated with the industry 4.0 concept, is without doubt a great help to increase the usefulness and efficiency of assets, improving both its operation and maintenance. For example, large data collection allows scheduled maintenance according to the different mission profiles, reducing costs by preventing unnecessary actions, and tasks etc. All intended to a result where it is increasing easiness, flexibility and immediacy of the spare parts, an improvement of maintenance policies, customizing them, as well as other aspects which, in summary, affect the parameters of assets reliability, availability, maintainability and safety.

As future lines of action and research, it is suggested the development of unified and simplified protocols for analysis and work processes. Depending on the case, it will be desirable to observe the applicability of methods of artificial intelligence (Machine Learning, Deep Learning), framed initially (for simplicity) in the concept of Integrated Logistic Support 4.0 for the establishment of decision-making processes, flow data and organizational structure that can certainly be implemented in the own assets ILS. As an academic added value, this paper stands aligned with the principles established by the current international defense sector, in the search for greater logistic efficiency [22] through an interconnected system among the members (Armies, Governmental Organizations and Companies from the allied countries), where innovation is encouraged and promoted [1], [16]. Finally, note that having operational armed forces requires today an advanced and competitive technological and industrial manufacturing. It should be a priority strategic objective for the industrialization and modernization of the defence sector.

REFERENCES

[1] Sanjurjo J.M. (2016). El futuro tejido industrial. XX Congreso Internacional de dirección e Ingeniería de Proyectos. Cartagena, julio 2016.

[2] UNE-EN 15341 (2007). Indicadores principales de desempeño de Mantenimiento. European Standard. CEN (European Committee for Standardization), AEN/CTN, INGEMAN, España.

[3] Jardine A. (1999). Measuring maintenance performance: a holistic approach. *International Journal of Operations and Production Management,* 19(7): 691–715.

[4] Parra Márquez C.A., Crespo Márquez A. (2015). Ingeniería de Mantenimiento y Fiabilidad aplicada en la Gestión de Activos. INGEMAN (Asociación Española para el Desarrollo de la Ingeniería de Mantenimiento). ISBN: 978-84-95499-67-7.

[5] Campbell JD, Jardine AKS. (2001). Maintenance excellence. New York: Marcel Dekker.

[6] Bulow, J.I. [1982]. Durable Goods Monopolists. *Journal of Political Economy*, 90: 314–332.

[7] Colwell, P.E. [1991]. Functional Obsolescence and an Extension of Hedonic Theory. Journal of Real Estate Finance and Economics, 4: 49–58.

[8] Handfield, R.B. & Pannesi, R.T. [1997]. Managing component life cycles in dynamic technological environments. *International Journal of Purchasing and Materials Management,* 30(2): 19–27.

[9] Bradley, M. & Dawson, R.J. [1998]. An analysis of obsolescence risk in IT systems. *Software Quality Journal* 7: 123–130.

[10] Iselin, D.G. & Lemer, A.C. [1993]. Fourth Dimension in Building: Strategies for Avoiding Obsolescence. National Research Council Staff, National Academies Press.

[11] Lemer, A.C. [1996]. Infrastructure obsolescence and design service life. *Journal of Infrastructure Systems* 2(4): 153–163.

[12] Trowbridge, C.R. [1964]. Deterioration. Appraisal Journal, January: 91–6.

[13] Lee, I.H. & Lee, J. [1998]. A Theory of Economic Obsolescence. *The Journal of Industrial Economics* 0022–1821 Volume XLVI September No. 3.

[14] Akgül, F. & Frangopol, D.M. [2004]. Time-dependent interaction between load rating and reliability of deteriorating bridges. *Engineering Structures* 26: 1751–1765.

[15] Mansfield, J.R. & Pinder, J.A. [2008]. Economic and functional obsolescence: Their characteristics and impacts on valuation practice. *Property Management* Vol. 26 No. 3: 191–206.

[16] GTAI (2014). Industrie 4.0–Smart Manufacturing for the Future. Germany Trade & Invest, Berlin, Germany (2014). www.gtai.de.

[17] Bonvillian W.B. (2013). Advanced Manufacturing Policies and Paradigms for Innovation. Science. Vol. 342, Issue 6163, pp. 1173–1175. DOI: 10.1126/science.1242210.

[18] Martorell J. (2017). Nueva organización del Mando del Apoyo Logístico del Ejército del Aire. El ciclo de vida y las nuevas tecnologías. Symdex 4ª Edición. Madrid, Junio 2017.

[19] Guillen A., Gonzalez-Prida V., Gomez J., Crespo A., Turconi G., Ventola G. (2017). Maintenance 4.0. Review of maintenance role in the industry 4.0 revolution. Ed. Taylor and Francis, CRC Press: Safety and Reliability—Theory and Application: ESREL 2017.

[20] González-Prida V., Crespo A. (2014). After-sales Service of Engineering Industrial Assets. A Reference Framework for Warranty Management. London: Springer-Verlag.

[21] Hernán A.B. (2017). Modelos predictivos en el MALE basados en RBS. El ciclo de vida y las nuevas tecnologías. Symdex 4ª Edición. Madrid, Junio 2017

[22] Lambert, K.R.. (2017). Supporting high-technology systems during periods of extended life-cycles by means of integrated logistics support. *South African Journal of Industrial Engineering,* 28(1), 125–132.