# Chapter 25
# Beyond RAMS Design: Towards an Integral Asset and Process Approach

**A. Martinetti, A.J.J. Braaksma and L.A.M. van Dongen**

**Abstract** The lifespan to which assets can be efficiently maintained, upgraded or disposed, heavily depends on the characteristics designed into the asset in the design phase. RAMS analysis is a well-established approach often used to reach this target. This approach is however not adequate for handling the complexity of changes and demands placed on nowadays assets. This can lead to reduced performance and unnecessary risk taking. There is a need for a more integral RAMS (SHEEP) perspective including Supportability, Health, Environment, Economics and Politics. Additionally there is often only focused on the asset itself and not on processes supporting the maintenance of an asset. Therefore this chapter does not only give a historic overview on RAMS evolvement, but also aims at answering how the supporting processes can be designed from an integral RAMSSHEEP perspective. We illustrate this by analysing the functional requirements for the Toilet System (TS) of the Sprinter Light Train (SLT).

## 25.1 Introduction

The product's Reliability, Availability, Maintainability and Safety (RAMS) are very important characteristics that have to be embedded and designed into every product or asset. This is because design decisions have a large influence on these characteristics. For example the expenditures are made during the equipment's life time, but those costs are already, for a large part, committed during the development stage of the equipment's life cycle. A re-design of components and parts during the later life cycle stages can have a strong influence on the maintenance efforts [18].

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Previous research already pointed out the importance of considering maintenance in planning the product life cycle [24], RAMS is considered a strategical, tactical and operational, risk-driven maintenance concept, in which a system's or asset's Reliability, Availability, Maintainability and Safety have to be taken into account. RAMS is applied to facilitate competitive advantage for the product and to reduce the business risk associated with non-performance of products and systems [16]. The approach helps designer and analysts to get an indication of the performance of the functioning of a system.

As described also by the European Committee for Electrotechnical Standardization (CENELEC) [9], RAMS is "a qualitative and quantitative indicator of the degree that the system, or the subsystems and components comprising that system, can be relied upon to function as specified and to be both available and safe".

But nowadays, this vision is not more enough and additional step is required to address environmental and political requests at the same time. BCG [17] states that "business is on the verge of a major 'next wave' of asset productivity improvement —one that will go farther and be more difficult to achieve than past initiatives", identifying such as the exhaustion of traditional cost cutting. This challenge can be found in complex systems such as a railway system where transportation performance cannot be guaranteed just by technically perfect design concepts, but where the results are heavily affected by specific procedures, working regulations and working conditions. [21].

In the following sections we will first describe the elements of a full RAMSSHEEP methodology, then we take the method in a historic perspective, thirdly we will illustrate the application of RAMSSHEEP at our case company (NS) and finally we will present our conclusions.

## 25.2 RAMSSHEEP Methodology

The decision process represent a not negligible problem in terms of time and money when the product is a capital asset since the required services to provide support have to be determined for its entire life cycle [19]. Therefore, the evaluation decisions should include making decisions about not only the asset but also about the ancillary activities that it requires.

As mentioned earlier the RAMSSHEEP methodology aims to connect the well-known aspects of the RAMS approach with five essential parameters (Supportability, Health, Environment, Economics and Politics) in order to design, plan, realise, use and dispose an asset increasing the efficiency and reducing costs and environmental impacts [4]. Table 25.1 organizes and defines the nine elements of the methodology, pinpointing with the help of some sources the main characteristics of each point.

The nine described elements of the RAMSSHEEP approach can be divided in three macro-categories as represented in Fig. 25.1.: (1) RAMS (Reliability, Availability, Maintainability, Supportability) concerning the aspects related to

**Table 25.1** Elements of the RAMSSHEEP methodology

| Element | Definition | Contextualization |
|---|---|---|
| Reliability | "The probability that an asset can perform a required function under given conditions for a given time interval" [23] | The reliability of a train is for example 90%. This means that there is a certainty of 90% that the train could travel |
| Availability | "The ability of an asset to be in a state to perform a required function under given conditions at a given instant of time assuming that the required external resources are provided" [20] | The availability of a train is for example 85%. This means that the train should be operational circa 310 days/year |
| Maintainability | "The probability that following the occurrence of a failure of an asset will once again be operational within a specific time" [23]. | The maintainability of a train is for example 90%. This means that there is a certainty of 90% that the train will be put in service on time after a maintenance action[1] |
| Supportability | "The characteristic of an asset to influence the easiness with which logistic resources can be available at the right time at the right place" [18] | The supportability of an asset can heavily affect the logistic organization causing delays (waiting for spare parts, technicians, equipment available) during the maintenance operations and influencing the Mean Time To Maintain (MTTM) |
| Safety | "A state in which or a place where you are safe and not in danger or at risk" [3]; "Freedom from unacceptable risks of harm" [9] | The Safety has to be included to ensure a safe asset for the final users and safe working places for the personnel involved in the production and in the maintenance operations. To note, how the absence of safety could change the cost-effectiveness of an asset |
| Health | "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [27] | Health has to be included to ensure that an asset does not cause diseases for the final users and for the personnel involved in the production and in the maintenance operations |
| Environment | "The environment represents the earth, including rocks, soils, water, air, atmosphere and living things" [12] | The asset should reduce as much as possible, for example by using the Best Available Techniques (BAT) [10] the impact on the Environment during the entire life-cycle. Here lies the difference between environmental compatibility and environmental sustainability |

(continued)

**Table 25.1** (continued)

| Element | Definition | Contextualization |
|---|---|---|
| Economics | "The economic perspective is concerned with the financial aspects of the asset and its operation." [22] | The economic factors often drive the main direction and the investment from the design phase to the decommission phase of a product/asset |
| Politics | "The first definition of politics was used in the Aristotle's book Πολιτικά, Politika, referring to the *affairs of the cities*" | The politic decisions should affect the main direction of a capital assets investment pinpointing and underlining the needs of the community |

[1]To note that, in addition to the stochastic definition, the Maintainability could also represent the level of easiness to maintain an asset/product/component. In other words, how quickly maintenance activities can be performed reaching the required level of quality

maintenance management, reliability, logistic and spare parts, (2) SHE regarding all the criticalities that could cause injuries, fatalities, diseases and environmental disasters during the design, production operations, management and decommission and (3) EP including all the political and economic considerations and evaluations on the feasibility and need of the project for the society and, in general, for the market.

Adopting an automotive metaphor, the macro-categories have to work as the elements in a gearbox, providing the car requests (high torque when climbing hills and when starting at low speeds and low torque running at high speeds on level roads due the inertial momentum) at the right moment according to the situation's conditions. In the same way, RAMS, SHE, EP gears should provide during the design phase precise and essential information over the impacts of the project on the different aspects ensuring to reach as much as possible a design-effectiveness of the production system.

## 25.3 R, RM, RAMS, RAMS-LCC and RAMSSHEEP: Placed in Historic Perspective[1]

Looking back to the last six decades, we can identify a clear evolution of the dedicated approaches to ensure that products/assets could perform a required function under given conditions for a given time interval. The Fig. 25.2 should help to resume the observed improvements and changes, pinpointing how the demands moved from an exclusive product perspective (R, RM), to the awareness to ensure

[1]R (Reliability), RM (Reliability, Maintainability), RAMS (Reliability, Availability, Maintainability and Safety), RAMS-LCC (Reliability, Availability, Maintainability Safety—Life Cycle Cost).

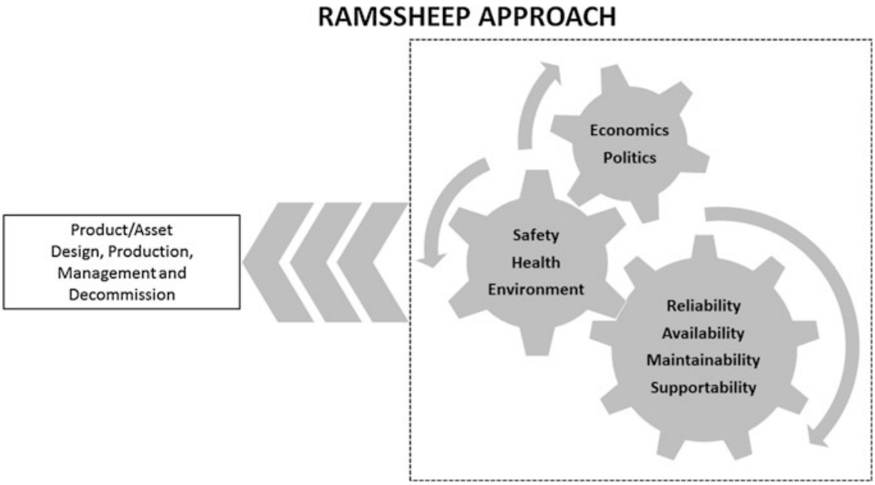


**Fig. 25.1** RAMSSHEEP: RAMS, SHE and EP elements working together as parts of a gearbox

safe products for workers and users (RAMS) to cost-optimization (RAMS-LCC) products, towards the need to ensure society approval and value (RAMSSHEEP).

The first structured approach of the Modern Age to evaluate the reliability in the industrial production process was introduced after World War Two in 1954 [13] during the First National Symposium on Reliability and Quality Control in the United States of America (US). The need of reliability was mainly fuelled by two different but connected events.

During the Second World War (i), 60% of the airborne equipment and spare parts arrived damaged and unserviceable before use, causing a remarkable waste of resources, energy, money, time and man-working hours. Due to (ii) the technological evolution, the complexity of the system and the number of system components increased (and it is still increasing), directly affecting the reliability of the entire system as shown in the example of Table 25.2 with a simple example. To better describe the importance of this phenomena, even more actual nowadays, the authors want to underline the different approach in terms of number of components used to design and build the Boeing 747 and the Mariner/Mars '64. The aircraft was assembled using more than 4.500.000 parts [1]; but for the spacecraft, since the success of the mission was strictly dependent on the reliability of every part, only 138.000 components [8] were used during the construction in order to reduce the number of unnecessary and unreliable elements.

In the '80s due to the high products demand, the necessity to increase the maintainability performance reducing the downtimes related to parts replacement and repairing offered the opportunity to dedicate more efforts on the design for maintenance aspects. The manufactures invested in using materials that did not prolong maintenance activities, using standard and universal applicable components, fasteners to accelerate maintenance activities, providing sufficient space

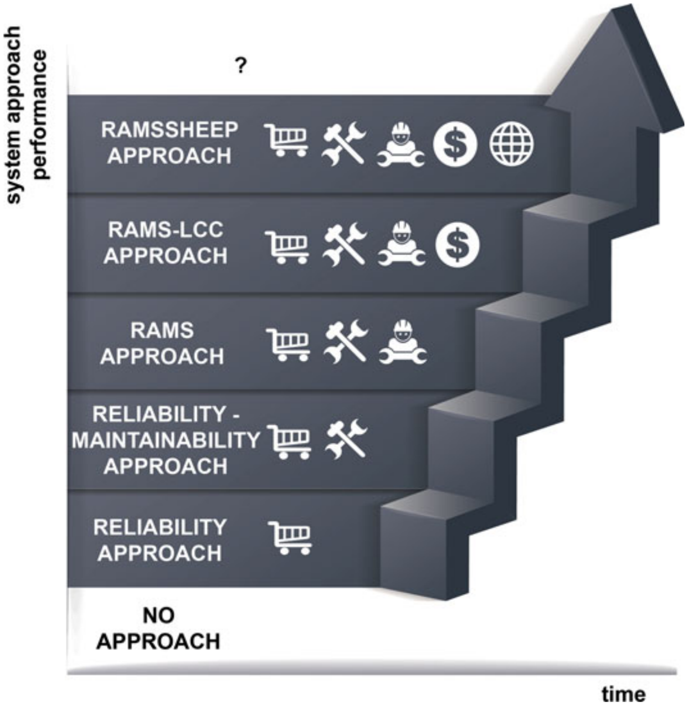


**Fig. 25.2** Evolution of the approaches for product/asset production

**Table 25.2** Reliability and increasing product complexity [14]

| Farm tractor model year | Number of critical components | Tractor reliability per year[1] [%] | Number of tractors failing per year/1000 tractors |
|---|---|---|---|
| 1935 | 1.200 | 88.7 | 113 |
| 1960 | 2.250 | 79.9 | 201 |
| 1970 | 2.400 | 78.7 | 213 |
| 1980 | 2.600 | 77.1 | 229 |
| 1990 | 2.900 | 74.8 | 251 |

[1] Assuming an average component reliability of 99.99% and critical components reliability-wise in series

around the maintenance points and designing equipment in such a way that it can only be maintained in the right way. Following the innovative vision called "Prevention through Design (PtD)" in terms of Occupational Health and Safety (OHS) proposed by the National Institute for Occupational Safety and Health (NIOSH) in the US, at the end of '80s the European Community decided to introduce several directives [5, 6], in order to oblige the employers to carry out an exhaustive Risk Assessment and Management analysis to provide safe and reliable machineries equipment, products and workplaces. Moreover, as a general approach, in the European Directives, the maintenance workers were identified as "workers who may be at increased risk", so that the need to conduct a separate Risk Assessment and Management for the maintenance activities becomes more evident and necessary [15]. The aforementioned evolution helps to embrace a more general approach already explained and well-known as RAMS. Not only the products/assets and their maintenance characteristics, but also the occupational conditions of the workers have to be taken into account.

Meanwhile, in an attempt to improve the design of products and reduce design changes, cost, and time to market, concurrent engineering or Life Cycle Engineering (LCE) was emerging as an effective approach to addressing these issues in competitive global market [2]. Dowlatshahi [7] underlined that the design of the product influences between 70% and 85% of the total cost of a product remarking how the designers have the opportunity to substantially reduce the Life Cycle Cost (LCC) of the product. As happened for the Reliability approach, the first motivation and incentive were provided by the weapons' market, stimulated by Department of Defence in order to reduce the operations and support cost that were accounted for 75% of the total expense [11].

Lastly, the development of the "Green Economy" theory defined as "low carbon, resource efficient, and socially inclusive (where) growth in income and employment should be driven by public and private investments that reduce pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" [25], forced to include environmental awareness to the production system to decrease carbon emissions and ecological footprint.

## 25.4 Design for RAMSSHEEP: A Case Study on an Existing Capital Asset (Toilet System) in Dutch Railways

To illustrate the opportunities offered by the RAMSSHEEP methodology on a real case, a test study on a capital asset is provided. The Dutch Railways (Nederlandse Spoorwegen, NS) have to place new Toilet Systems (TS) in the Sprinter Light Trains (SLT) not designed to have them due to the very short distance to run between two stations for which they were projected. Unfortunately, after a first working period the public opinion complaints forced the owner to rethink the first decision starting an evaluation process in order to add the TS.

The goal of the application is to devise the implementation of TS into the trains using RAMSSHEEP-principles which should lead to design criteria helping to focus on alternative design solutions.

The importance of a careful, detailed and integral life-cycle design of the TS for the SLT is also enhanced by the failure data provided by the asset manager. As stated in [26], the 13% of the failures of the rolling stock are attributed by technical problems occurred to the TS.

To provide and create a brief impression about the possible layout of the major TS sub-systems the analyses are also coupled to some design requirements (considered as pre-requirements by the asset owner and not included in the RAMSSHEEP approach):

- TS should be situated at the multifunctional vestibule;
- TS should be equipped with a vacuum toilet system which will be connected to a biological wastewater treatment system (bioreactor);
- The semi-closed wastewater treatment system should process the human waste in order to separate solids and fluids that will be biologically treated with aerobic and anaerobic processes.

### *25.4.1 RAMSSHEEP Principles Applied on the TS*

Since NS requires a high-standard system, a long detailed list of technical specifications is analysed in order to match them with the principles of the RAMSSHEEP methodology.

The full list of the most important requirements is composed by 127 functional elements which were arbitrarily categorized by the students involved in the process. This analysis showed that besides the RAMS (57%) principles, the SHEEP (43%) principles represents an important part to be included in the design of an asset (R (20%), A (5%), M (10%), S (22%), S (16%), H (9%), E (7%), E (2%) and P (9%)).

An example of technical specifications of the SLT TS, as provided by NS, are shown according to each specific principle (Table 25.3). This approach gives the opportunity to consider in the evaluation every aspect of the problem in a “future-proof” vision.

To create a connection between the RAMSSHEEP approach and pre-requirements, the TS is divided into five subsystems (outside design, duty system, water system, sensor system, and personal care) during the design phase in order to make the design and the design choices as more efficient as possible.

Moreover, during the design process of the subsystems the users, cleaners and maintenance technicians were taken into account in order to create a TS able to be maintained and accessible from the inside regardless of the location, such as a train station or a workshop.

**Table 25.3** An example of RAMSSHEEP principles applied to a few of the supplied TS requirements

| Reliability | Availability | Maintainability |
|---|---|---|
| The toilet should not have negative influence on the reliability of existing systems and should guarantee a MTBF of at least 40.000 h. The lifespan needs to be at least 30 years | The toilet, including the waste water treatment system and the fresh water system, should have a capacity sufficient for the number of passengers | Components of the toilet should be positioned in such a way that it provides easy access for the maintenance procedures |
| Safety | Supportability | Health |
| The toilet should offer an adequate level of safety in the event of a collision or derailment during normal service | The toilet should use standard, universally applicable components, tools and parts | The toilet should be easy to clean since people would be reluctant to use them if they are dirty |
| Environment | Economics | Politics |
| Application of hazardous waste on the product should be avoided as well as contaminating chemicals which can impact the environment | The LCC of the toilet system should be within the financial boundaries | The toilet should be installed even in trains meant for short commuting |

The combination of technical specifications and pre-requirements with the RAMSSHEEP approach gives the advantage to design a concept solution able to fulfil the most important aspects in order to have a Reliable, Available, Maintainable, Safe, Supportable, Healthy, Environment-friendly and Economic and Politic-feasible system as shown in Fig. 25.3.

Therefore, the minimal and simple design created with the RAMSSHEEP principles offers several advantages from a long term prospective. Most of the maintenance tasks are carried out on a human-handling level and do not involve lifting heavy parts (waste bags could be dragged over the floor, the dispensers and hand dryers could be cleaned avoiding un-ergonomic positions). The technicians should be able to solve most of the failures without docking the train at the workshop. The outside hatches should permit accessing the bio filter, chemical box and water reservoirs during extensive maintenance periods. The technicians could access the electricity and water reservoir panels from the inside in order to fix problems quickly during unexpected downtime situations.

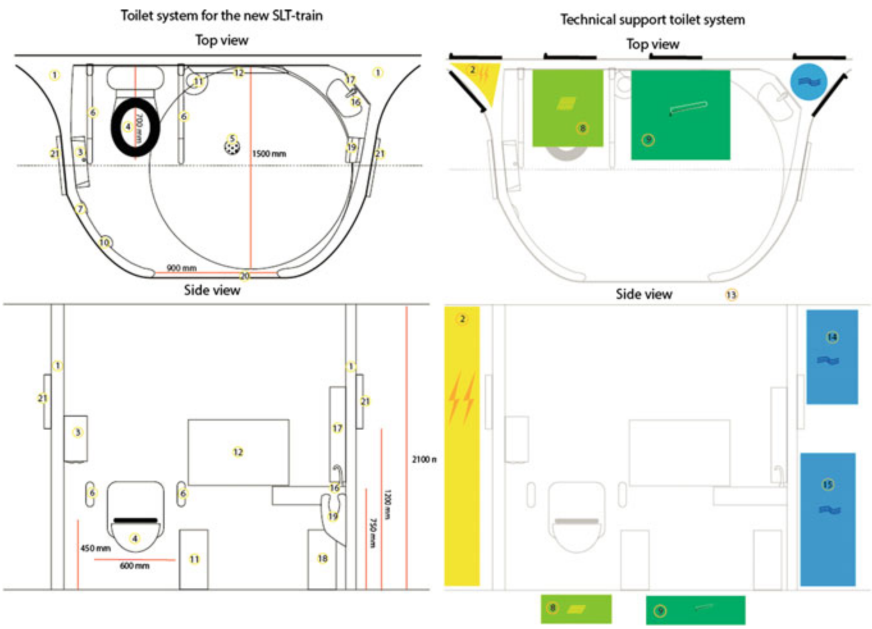


**Fig. 25.3** Overview of complete design concept (1. Outer casing, 2. Electricity panel, 3. Toilet paper, 4. Toilet bowl, 5. Drain, 6. Armrests, 7. Flush button, 8. Bio-filter, 9. Chemical box, 10. Help-button, 11. Hygiene box, 12. Nursery, 13. Heating and air-conditioning, 14. Water reservoir tap, 15. Water reservoir toilet, 16. Tap, soap dispenser, 17. Mirror, 18. Bin, 19. Hand dryer, 20. Door, 21. Information screens)

## 25.5 Conclusions and Recommendations

Our literature review showed that the RAMS(SHEEP) Methodology has evolved from purely technically centered (Reliability and Availability) to incorporate also Maintainability and Safety concepts. Due to quicker changing environments and more critical demands (e.g. legislation and political influences) there is a need for taking additional factors into consideration. The exemplary case of the Toilet System at NS clearly illustrates that requirements nowadays should include SHEEP factors besides the well-known RAMS. The weighting of the individual elements in the design of assets is moving from a pure technical and cost perspective to a more value based evaluation. RAMSSHEEP analysis is primarily aimed at the design phase of an asset but has potential to be used during the entire life-cycle management. Further research should be performed on how to re-use and update existing analyses during the life-cycle.

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