

DEVELOPING ACTIONS TO MINIMISE AVOIDABLE WASTE AND ITS CHALLENGE TO PLANT SAFETY[†]

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Purpose: Considering the UK's limited capacity for waste disposal (particularly for hazardous/radiological waste) there is growing focus on waste avoidance and minimisation to lower the volumes of waste being sent to disposal. The hazardous nature of some waste can complicate its management and reduction. To address this problem there was a need for a decision making methodology to support managers in the nuclear industry as they identify ways to reduce the production of avoidable hazardous waste. The methodology we developed is called Waste And Source-matter Analysis (WASAN). A methodology that begins the thought process at the pre-waste creation stage (i.e. Avoid).

Design/methodology/approach: The methodology analyses the source of waste, the production of waste inside the facility, the knock on effects from up/downstream facilities on waste production, and the down-selection of waste minimisation actions/options. WASAN has been applied to case studies with licencees and this paper reports on one such case study – the management of plastic bags in Enriched Uranium Residues Recovery Plant (EURRP) at Springfields (UK) where it was used to analyse the generation of radioactive plastic bag waste.

Findings: Plastic bags are used in EURRP as a strategy to contain hazard. Double bagging of materials led to the proliferation of these bags as a waste. The paper reports on the philosophy behind WASAN, the application of the methodology to this problem, the results, and views from managers in EURRP.

Originality/value: This paper presents WASAN as a novel methodology for analyzing the minimization of avoidable hazardous waste. This addresses an issue that is important to many industries e.g. where legislation enforces waste minimization, where waste disposal costs encourage waste avoidance, or where plant design can reduce waste.

The paper forms part of the HSE Nuclear Installations Inspectorate's desire to work towards greater openness and transparency in its work and the development in its thinking.

KEYWORDS: decision making methodology, plastic bags, waste management, waste minimization

PAPER TYPE: Research paper

INTRODUCTION

In the UK there is a growing focus on waste avoidance and minimisation and the Waste Management Hierarchy (Cabinet-Office, 2002) is one of the government's strategies to encourage critical thought about this challenge. The intention of much of this effort is to reduce the amount of waste that goes to disposal, not least because the capacity of waste disposal is reducing, especially for non-conventional wastes (e.g. hazardous, radiological waste).

The key principle from this which is developed within this paper is to move thought processes in waste management to "Can I avoid producing waste?" from "I have a waste what should I do with it?"

Another important issue is the need to ensure that the ongoing management challenge from hazardous waste is minimised, not least by providing ongoing support to managers as they seek to understand and control waste-producing processes so that they can make process improvements that do not have negative impact elsewhere in the system.

Risk and safety can be greatly compromised by the presence of hazardous waste, for example, caustics, heavy oils as well as radioactive materials. While some of these wastes are unavoidable in that they have been designed into the process, the production of other waste is avoidable as the waste results from processes failing in some way and moving away from their original design state (i.e. unexpected queues build up, causing a slowing in throughput/processing time, resulting in avoidable waste production). Although active management of wastes may seek to avoid waste creating secondary risks from processes going out-with design, there is an added presence of secondary risks from potentially hazardous materials continuing to be created.

For example, if combustible materials are stored without effective management regimes in place then fires may result, or if ventilation systems are not monitored and managed then waste can amass in these systems resulting in avoidable impact on plant staff as well as plant stoppage

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when the systems unexpectedly break or need to be overhauled due to a lack of programmed ongoing maintenance.

The range of potential risks encourages plants/processes designers to reduce unavoidable waste during the design phase (i.e. design waste production out of processes), and these risks also encourage plant managers to ensure that processes remain within the designed parameters to reduce avoidable waste (i.e. avoidable waste should not be produced when the system is working as designers intended). Without attentive management, wastes (hazardous and non-hazardous) can be produced that take substantial effort and money to store until a suitable process is available to reduce that waste or until this waste is disposed of. Also, avoidable wastes can be problematic for the same duration as unavoidable wastes, meaning they present an ongoing (and potentially unexpected) challenge for managers.

In the nuclear industry, there has been a history of accumulation of difficult or challenging wastes. For some decades, the lack of adequate treatment processes or outlets have led to a proliferation of hazardous waste which is poorly characterised, leading to significant challenge to the managers of that waste of clarity on what they are facing to deliver the best approach to manage the waste. Consequently, more hazardous waste is produced from these situations when systems are not available (or do not exist) to process this poorly characterised waste meaning the materials are being stored in conditions which encourages the production of even more avoidable waste. The risk and hazard which accompanies these wastes is concerning, not least when designers have not yet developed removal/processing options (and so no apparent processing route yet exists) or when some aging facility/infrastructure fails unexpectedly which further delays characterisation/recovery especially if replacement equipment needs to be redesigned.

In this paper we describe a new methodology for thinking about waste minimisation that begins the thought process at the pre-waste creation stage (i.e. Avoid). The methodology, called Waste And Source-matter Analysis (WASAN), helps plant/process managers to think through the causes of avoidable waste production and potential options that can be implemented on plant to avoid/reduce waste. WASAN aims to help managers to avoid reinventing the problems of the past through providing a methodology to develop solutions to avoidable waste production. We report as part of the desire to work towards greater openness and transparency on the development of waste management guidance for the UK's Health and Safety Executive (HSE) and this does not currently represent its final regulatory view.

ADDRESSING THE CHALLENGE

Underpinning WASAN is the need to think about how material and/or a plant can be closely managed before the avoidable waste is created, consequently, we focus on the management of the source of waste (what we call the "source-matter"). There is a need to take an operational view of source-matters to understand their behaviours in different waste management regimes, and this allows us

to identify what managers can do to try to prevent the proliferation of waste when operations fall outwith design. Simultaneously, there is a need to take a strategic view of source-matters to understand how to avoid waste generation when processes fall out-with design. In particular this is important when materials transfer between operations/plants as one operation/plant may support/impinge on the others when they fall outwith design. Hence it is necessary to take a more holistic view (across plants) to understand the nature of the impact that outwith design operations have on up/downstream plants. By taking operational and strategic views of source-matters, we are able to identify actions that can enhance the management of these materials. This thinking aims to deliver analysis that is:

- Structured, to ensure appropriate decomposition of our understanding of waste minimisation problems and resolutions in a way that important issues are clearly understood and recorded.
- Rigorous, to ensure that managers have sufficiently interrogated alternative explanations and responses in sufficient depth and breadth that they have confidence in their conclusions.
- Systematic, to ensure that all source-matters are analysed similarly and in sufficient breadth and depth to the extent that the system of waste production is understood in a structured and rigorous manner.
- Systemic/holistic, considering the implications on the management of waste/plants from the need to move waste across operations/plants i.e. thinking about waste minimisation at a wider (systems) level which may stem beyond a single plant.

A component of good practice is the development of a rigorous and transparent decision making audit trail of lasting quality that is understandable to those who may not have contributed directly to its development. This is especially important where hazards extend across generations (e.g. asbestos, radioactive waste) and so different successions of staff/generations might need to know what has gone before. Also, it is important to distinguish within any analysis the difference between wastes: We define those wastes that are designed into processes and arise (or are predicted) from normal operations as *unavoidable* without process re-design. Other, or additional quantities of, wastes that are not designed into processes and result from operations falling outwith-design we regard as being *avoidable*.

We developed a group workshop methodology, called Waste And Source-matter ANalysis (WASAN) (Shaw and Blundell, 2009), which aims to support the analysis of source-matters. WASAN was developed for plant managers and other stakeholders to use when they want to develop actions to safely minimise/prevent their generation of the avoidable waste that is associated with source-matters that are under their control. The methodology can be used by process managers to analyse: (1) the behaviour of a process, (2) waste minimisation inside that process, (3) consequences for waste production from up/downstream processes falling out-with design.

WASAN was inspired by good practice industry methods such as: the Waste Management Hierarchy which offers the stages through which people can consider the waste management challenge e.g. how can you avoid/minimise/reuse/etc. waste (Cabinet-Office, 2002); HAZOP (Hazard Operability Study) which analyses where hazards may occur in a system so that they can be addressed to reduce their likelihood or their consequences if they happen (Kletz, 2006); and the HSE's Enforcement Management Model which helps inspectors to assess what is a proportionate response if they suspect that there may have been a breach of law/guidance (HSE, 2005).

A WASAN workshop can be run at any stage of design, operation or decommissioning of a waste-producing process. It will involve key stakeholders (e.g. process experts, implementers, knowledge holders) who use the stages of WASAN to analyse the system and develop actions that are both technically feasible (in terms of suitably addressing the waste minimisation challenge) and politically feasible (in terms of being culturally acceptable to the wider stakeholder groups). From Figure 1, WASAN's stages of analyses include:

- a. Define the process facility and wastes (i.e. establish the boundary of the system under analysis).
- b1. Analyse waste production inside the process facility (internal operations).
- b2. Analyse waste production resulting from the impact of up/downstream facilities (external operations).
- c. Evaluate that actions that have emerged from "a, b1 & b2" to understand which actions can be implemented to have the desired effect on the system.
- d. Programme deliverables into the wider workplan so that effort can be allocated to their implementation.

Although these stages are presented as being separate, WASAN is designed more as a fluid methodology which allows the analyses to cycle back and forth through the stages to enable the stakeholders to flexibly consider waste minimisation activities. However, the flexibility is curtailed by having to consider stages a–d at some point during the analysis as each is critical to building the holistic picture of the situation and ensuring that actions are selected/implemented with a view of their wider implications on

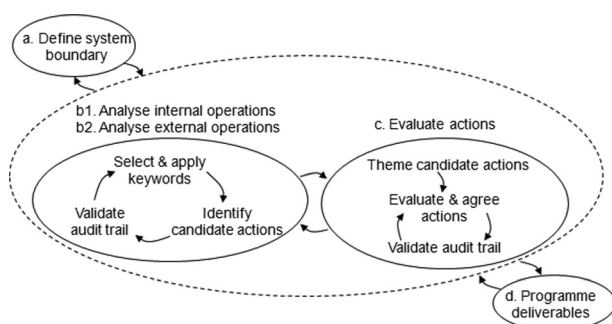


Figure 1. WASAN's generic structure

the broader system of operations. The analysis does not need to be done at a single sitting but can be built up over a series of workshops.

APPLYING WASAN: A CASE STUDY

We used WASAN with senior staff in the Enriched Uranium Residues Recovery Plant (EURRP) at Springfields (UK). The challenge that they wanted to explore was the problem of generating many plastic bag waste as a result of EURRP operations. The plastic bags are used to contain alpha bearing nuclear matter as it is transported around EURRP and the wider site but, because of the number of plastic bags that are used in these operations, there is a sizeable cost and volume of waste being generated especially as a result of double bagging. Double bagging is a protective measure that is taken when the first bag is compromised in some way and a second bag is used to contain the materials that may emit from the first bag. EURRP staff were aware that this was a potentially avoidable waste stream that required a significant response from operations. By reducing this waste stream, EURRP could potentially save time, money and processing capacity whilst maintaining safe operations. Below we present some of the results from this application of WASAN to EURRP, but we present a simplified version for readability.

STAGE A – DEFINE SYSTEM BOUNDARY

Aim: To establish the boundary of the analysis and define key properties.

Technique: A process of drawing the facility/wastes and writing definitions of these. By constructing a wiring diagram of plant and operations the group learn their properties and establish working assumptions. Through agreeing definitions the group crystallise and record their emerging agreement.

Illustration: In discussing EURRP, the group defined:

- The *source-matter*: "Soft residues", anything that is not hard e.g. paper, cloths.
- EURRP's *aim* in processing the source-matter: To remove all the uranium that can be returned to the uranium to the fuel cycle. The material that cannot be returned to fuel cycle is disposed of off-site.
- Engineering, physical, managerial *safeguards* that aim to prevent avoidable waste: Double bagging to prevent release as a contamination control and small bins for containment.
- The avoidable *wastes*: Plastic bags that contain the waste; ISO freight containers that contain bagged waste; cable ties for bags.

Our focus was plastic bags which were defined as:

- The *reasons* the plastic bags are generated: The over use for ease of handling and containment.
- Their physical *form* is: Plastic so the more plastic bags used the more sodium nitrite needed to decontaminate them.

	What are the issues [[actions]] around AVOIDING the generation of this waste	What are the issues [[actions]] around PREPARING THE DISPOSAL of this waste
plastic bags	Double bagging builds confidence in safety - so the issue is to build confidence that other forms are equally safe [[Consider alternative reusable containments e.g. lids on bins so no bags]]	The need for double bagged containment, rather than single bagging [[Consider an alternative way of achieving the same containment with a single plastic bag]]

Figure 2. Issues and **[[candidate actions]]** for B1

- Optimal *conditions* for managing the waste: Question the need for other facilities to segregate wastes as they use more bags and EURRP combines it all together. Consider conducting daily waste collections to send (non-)contaminated waste to the right processes.
- *(B)ehaviour* of the plastic bags so management can control this: They clean up very well when washed. If sodium nitrites were not used then the contaminant would not be removed as readily.

STAGE B1 – ANALYSE INTERNAL OPERATIONS

Aim: To systematically identify issues in minimising the generation of waste inside a process.

Technique: The Waste Management Hierarchy (WMH) conceptualizes waste management through advocating (1) waste *avoidance* as a first priority, (2) waste *minimization* as second. If impossible then (3) *reusing* waste, (4) *recycling* elements, or (5) *recovering* parts of waste is advocated. (6) *Treating* waste prior to (7) *disposal* are least desirable. The WMH’s structure provides keywords that are applied to analyse how each waste can be avoided, minimised, reused, and so on. Actions are agreed for waste reduction themes and an audit trail is recorded.

Illustration: Figure 2 shows two issues and actions from analysing how plastic bags can be avoided and prepared for disposal. Coincidentally, both analyses result in actions that strive for alternative containment solutions. Applying all WMH keywords allows a systematic analysis of each waste.

STAGE B2 – ANALYSE EXTERNAL OPERATIONS

Aim: To systematically examine the effect of “outwith-design” transportations of materials between facilities on waste generation inside the process facility e.g. upstream facilities transporting too much or the process facility being unable to transport expected levels downstream.

Technique: A two-step approach was developed based on qualitative sensitivity analysis and HAZOP.

1. *Define transportations immediately into/out of the process facility:* Picturing the inter-linked facilities helped to identify these transportations, and writing definitions crystallised learning and recorded agreements on their nature.
2. *Apply keywords to transportations to conduct sensitivity analysis:* Keywords were selected to represent states of being outwith-design e.g. too much (material), too little. Applying keywords is influenced by HAZOP and so every transportation is subjected to each keyword to consider the effect of it being outwith-design. Following this, actions are agreed to address concerning themes and an audit trail is recorded.

Illustration: To illustrate the definition of the transportation of plastic bags:

- How plastic bags are *transported* into EURRP: In bins from upstream facilities.
- Issues in the *management* of the transportation, to identify potential mal-operations. Plastic bags are checked and, depending on their contents, go to one of three routes – thus not all require processing in EURRP.
- How *up/downstream* facilities may cause transportations mal-operation: Being unable to send processed material to downstream facilities will eventually prevent EURRP from accepting new material.

To illustrate the application of keywords, we select one transportation of plastic bags into EURRP from an upstream facility. In Figure 3, both states of outwith design transportations result in avoidable waste either due to loss of containment or backlogs of waste.

	What are the concerning issues [[actions]] of on the management of soft residues ?
No plastic bags being transported along Contact Enriched Plants > EURRP	• Containment issues as the material would fall out everywhere and have radiological air levels [[Find an alternative form of containment for current arisings]]
More than normal plastic bags being transported along Contact Enriched Plants > EURRP	• We would accumulate waste in excess of the throughput of the plant [[Ensure that future site strategies consider the EURPP throughput]]

Figure 3. Issues and **[[candidate actions]]** for B2

STAGE C – EVALUATE ACTIONS

Aim: To systematically evaluate potential actions.

Technique: The safety-based philosophy of “As Low As Reasonably Practicable” (ALARP) (HSE, 2001) aligned with our view that waste will never be zero but can be safely reduced within reasonable cost/benefit returns. To operationalise ALARP in a decision making methodology, we took lessons from the Enforcement Management Model (EMM) that helps Inspectors to decide what response is made to a breach of law. We developed a new technique, called the Action Evaluation Grid (see Shaw and Blundell, 2009), which uses a similarly structured approach to the EMM to evaluate the attractiveness of actions to reduce waste to ALARP against criteria using defined measures.

The development, evaluation and down-selection of actions follows a 5 stage process:

1. Establish themes: The multitude of issues and candidate actions discussed in Stages A, B1 and B2 are analysed to reduce duplication as well as structure the diversity of thoughts into a more manageable set (see Figure 4). Themes emerge from the audit trail of the discussions captured in Stages A, B1 and B2 and should represent the major issues that the group feel need to be considered for effective waste minimisation.
2. Establish recommendations: Once the themes are verified as covering all the important issues, the group can consider their recommendation for addressing each theme. A recommendation may combine a number of different aspects of previous discussions i.e. multiple recommendations to address a theme adequately.
3. Propose actions: Each recommendation is further detailed by proposed actions that convey the activities to meet the recommendation.
4. Evaluate actions: Given the multitude of potential actions, actions need to be evaluated and prioritised to

understand which are thought to have reliable, high impact. The Action Evaluation Grid (Figure 5) is used as a visual means to quickly evaluate and compare the potential of each action.

5. Agree timing of deliverables and responsible individuals: Using the outcome from the Action Evaluation Grid, deliverables are agreed. The timing and logical completion of actions needs to be considered as some activities may depend on others and so their timing needs to be coordinated to ensure appropriate project management of the suite of activities (see Figure 6). It is important to note that although the EMM has been used to inform the development of this process the deliverables and timings are not regulatory hold points but operator owned deliverables.

Illustration: The actions identified in Figures 2 and 3 were themed by the group and general recommendations and proposed actions were discussed and agreed. Figure 4 can be used to present the themes that are contained in the discussions up to this point, as well as capture the general recommendations, more specific actions to address each recommendation and then the firm/timed deliverables that address each specific action.

Figures 4 and 5 illustrate the outcome from a Stage C analysis but these are for illustration only – they are not the actual outcomes.

The proposed actions can be evaluated in the Action Evaluation Grid (Figure 5) against selected criteria. We have been using three criteria, each with 3–4 measures with which to evaluate the performance of proposed actions, as detailed in Figure 5. Each proposed action is assessed in terms of how it performs against the criteria and is subsequently positioned in the right hand column of Figure 5. In this illustration, the evaluation of action A2a indicated that it should produce benefits of “significant waste savings”, it is a “well defined and proven” technology

Themes	Recommendations	Proposed actions to the Action Evaluation Grid	Who is responsible	Deliverable/timescale
Explore if plastic bags as an avoidable waste is a significant problem and what the size of the problem is	R1) Understand the size of the potential problem i.e. the avoidable waste that is generated	A1a) Identify a local waste measure for plastic bags and implement a process for measuring	GH	D1a) Implement a measure for plastic bags by 31st May (this year)
		A1b) Assess how many bags we use and evaluate whether this is excessive	GH	D1b) Commission a working party to explore. Findings due 15th July (this year)
Question the need to double bag and consider alternative forms of containment	R2) Review the use of plastic bags	A2a) Consider a reusable container to replace plastic bags in between processes	IJ	D2a) Commission a working party to make proposals. Proposals due 31st December (next year)
		A2b) Examine the safety case and the history behind double bagging to see if we can single bag or use alternative	KL	D2b) Have a summary of the findings by 31st December (this year) and an interim proposal for the way forward by 31st March (next year)
		A2c) Explore if there are other process reasons for generation of waste (plastic bags)	MN	D2c) Commission a working party to explore. Findings due 31st October (this year)
Ensure that future strategies for the site consider EURRP throughput	R3) Consider the role of EURRP in the wider site strategy	A3a) Establish the future of EURRP in future site strategies	IJ	D3a) Commission a working party to explore the strategic role of EURRP in the site, by 31st March (next year)

Figure 4. Deliverables for Stage C (just for illustration)

What is the realistic benefit from implementing the recommendation?	How sure are we of the recommendation working adequately?	How long to reach the point of implementation?	Evaluating actions against the criteria
significant waste savings	well defined and proven	within 1 month 1-3 months +3 months but within financial year beyond financial year	A2a) Consider a reusable container to replace plastic bags in between processes
	adequately defined and analogues exist (other examples of it working)	within 1 month 1-3 months +3 months but within financial year beyond financial year	A2b) Examine the safety case and the history behind double bagging to see if we can single bag or use an alternative
	no analogues exist and development could be required	within 1 month 1-3 months +3 months but within financial year beyond financial year	A3a) Establish the future of EURPP in future site strategies A2c) Explore if there are other process reasons for generation of waste (plastic bags)
lesser significant waste savings	well defined and proven	within 1 month 1-3 months +3 months but within financial year beyond financial year	
	adequately defined and analogues exist (other examples of it working)	within 1 month 1-3 months +3 months but within financial year beyond financial year	A1a) Identify a local waste measure for plastic bags and implement a process for measuring
	no analogues exist and development could be required	within 1 month 1-3 months +3 months but within financial year beyond financial year	A1b) Assess how many bags we use and evaluate whether this is excessive
minor waste savings	well defined and proven	within 1 month 1-3 months +3 months but within financial year beyond financial year	
	adequately defined and analogues exist (other examples of it working)	within 1 month 1-3 months +3 months but within financial year beyond financial year	
	no analogues exist and development could be required	within 1 month 1-3 months +3 months but within financial year beyond financial year	
must do			
should do			
could defer			

Figure 5. Action Evaluation Grid (just for illustration)

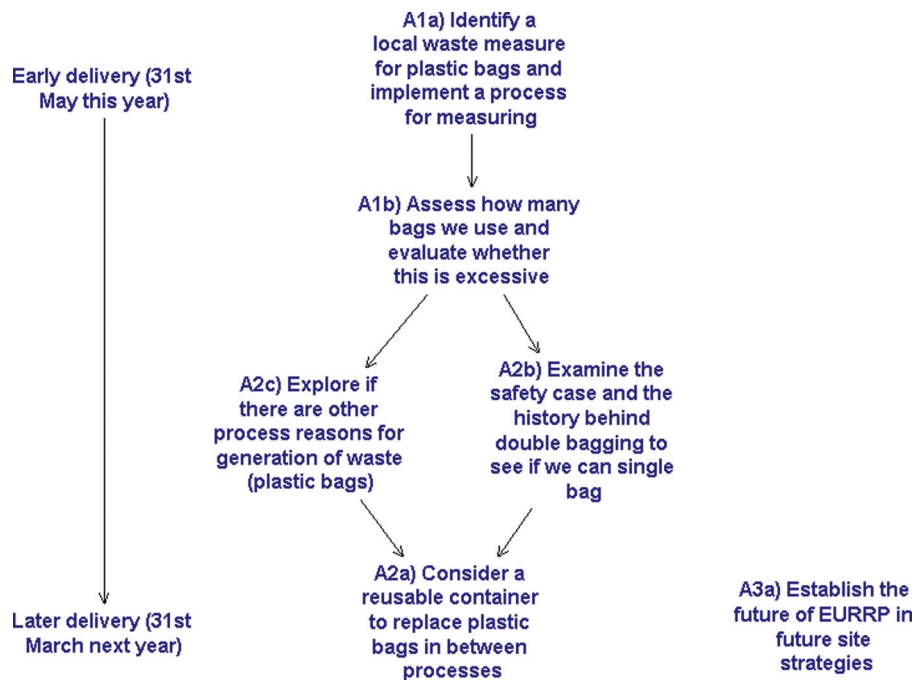


Figure 6. Timing of deliverables (just for illustration)

and should reach the point of implementation “within 1 month”. In contrast, action A3a is expected to produce benefits of “significant waste savings” but “no analogues exist” and it should take “1–3 months” to reach the point of implementation. There were no actions that could be deferred and so all actions were taken forward to the scheduling stage, in Figure 6.

The timing of deliverables may be dependent on one another e.g. if one deliverable enables another then this may need to be considered during scheduling. This is considered in Figure 6. The timing of deliverables is scheduled by considering:

1. The logical order of implementing actions.
2. The desired completion date.
3. The dependency between actions e.g. actions which need to be completed before/after others.
4. The constraints on delivering actions which may require the delay/bringing forward of actions e.g. resource, implementation, financial.

The analyses of the proposed actions suggest that only A3a does not directly affect the delivery of other actions and so can be delivered against its own timeframe. All the other proposed actions have dependencies and so their delivery timing needs to be set by taking account of the other actions. Consequently, we agree the precise dates with this in mind and put those dates in the deliverables column of Figure 4. The result of this work is a final proposal of timed deliverables.

STAGE D – PROGRAMME DELIVERABLES

Aim: To evaluate actions against global strategic priorities and programme these into deliverable workplans.

Technique: When working at a sub-system level, what appears to be rational might be irrational when considered at a higher level. Thus, we consider actions at the higher level to ensure they deliver higher strategic priorities. The audit trail communicates the rationale for (expected outcomes of) actions enabling evaluation of their merits in meeting high-order goals. This stage was not done for EURRP so is not illustrated here.

FINAL THOUGHTS

We suggest that WASAN may be applicable where a structured analysis of avoidable waste production is needed in a way that builds an audit trail of lasting quality. The methodology is flexible enough to be adapted to different waste minimisation challenges but aims to maintain the ability to develop a substantial audit trail to show the development

of waste minimisation options whilst showing the rejection of other options. The successful application of the methodology includes the need to:

- Select the right knowledge holders and stakeholders to participate in the WASAN to ensure that technical and political aspects that are uncovered can be resolved by those present.
- Effectively facilitate a group in exploring their understanding of the presence and cause of avoidable waste production, including the resolution of disagreements on the nature of the problem/solutions.
- Systematically deconstruct the waste challenge using the analytical structures offered by WASAN.
- Appropriate record discussions and agreements in a form that builds a substantial audit trail of lasting quality.
- Ensure that the outcomes/recommendations from the analysis are supported by a substantial business case/rationale to justify the (additional) resources that may be necessary.

Future research on the method will consider the link between HAZOP and WASOP to establish if there is a link between the faults identified in the HAZOP and how these might have impact on the waste generation being considered in the WASOP. For example, do faults have impact on the production of plastic bag waste and, if so, which are the key faults that might cause the most avoidable waste. From a waste minimization perspective, these would be faults to closely control.

We have applied WASAN in a narrow range of contexts and are continuing to seek other opportunities to apply it more widely to test its potential.

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