An Action Planning Model to Control Non-Revenue Water

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Abstract:
The authors have analysed a large sample of actions plans to control non-revenue water with the objective of evidencing the main causes for failure or success. Their conclusion is that any action plan needs to be considered under three dimensions for both design and implementation: the operational dimension, the project management dimension and the change management dimension. These three dimensions are the base of the proposed action planning model. Most utilities can deal with the operational dimension but it appears that the main causes for failure and lack of sustainability result in the underestimation or misunderstanding of both additional dimensions: project management and change management. The paper presents some basic recommendations in those areas.

The authors also outline a theory about the "dynamic management of loss" the non consideration of which causes many failures. They introduce some new concepts such as: the *coefficient of return of anomalies* (each time one regularizes some anomalies, new anomalies occur); the *migratory attribute of losses* (under certain conditions real losses may be transmuted into apparent losses, and vice versa); and the *time factor and visibility threshold* (every action has its own time factor). The understanding of these concepts is useful for the management of actions plans to control for non-revenue water.

Keywords:
Non-revenue water, Action planning, Project management, Change management,

1. Introduction

During the last decade, a huge effort has been made by many organizations, including the IWA, in order to promote new concepts and methods to improving efficiency in the management of water utilities and, in particular, in the reduction of Non Revenue Water. However it clearly appears worldwide that the level of NRW is not under control in most utilities: very often it continues to increase in an apparently unavoidable way. As shown in their post-appraisal reports, many financing agencies have spent huge amounts of money to reduce NRW and the results are often rather poor. It shows that improving definitions and concepts is not sufficient to address the issue, causes of failure need to be investigated in depth at the stage of action planning and implementation and a more systematic approach needs to be developed.

The authors have designed and implemented action plans to reduce and control NRW in many developed and developing countries on all continents. The establishment of any action plan always starts from the review and assessment of the current situation, and – what is often more important – from the audit of the former actions that have been implemented in the previous years. Considering both former action plans and new action plans the authors have established a very complete and significant sample about action planning in the field of NRW. The following conclusions are based on the review of more than 60 action plans, analyzing both causes for failure and success. From this survey it has been possible to outline an effective action planning model to control Non Revenue Water.

The authors believe that there is a gap between (i) the detailed concepts and specialized indicators that are now rather well known and (ii) the way to deal with them in the frame of an action plan. The objective of this paper is not to provide one more miracle formula, it aims at proposing a more systematic approach to both consultants and practitioners in order to avoid the usual traps and to build and realise winning action plans.

The reduction and sustainable control of non revenue water in a water supply system is more complex that many people believe. It is necessary to look into the topic from a holistic and multi-dimensional perspective. The prescriptive model-based approach that is presented hereafter is based on the usual

concepts that are well known by the IWA members and other professionals but it also develops some rather new approaches such as "the Dynamic Management of Loss", "Global NRW Project Management" and finally the" Change Management". But it is firstly necessary to remind how action plans are designed and implemented and to identify why they succeed or fail. Let us consider successively:

- The general theory of loss and what is missing
- The establishing of the water balance
- The design of the action plan
- The most frequent causes for success or failure
- The implementation of the action plan
- The change management scenario

2. The general theory of loss and what is missing

In any water supply system, like in any system, there is a ***natural entropic tendency to disorder***. Whatever their nature, the losses have an unfortunate natural tendency to increase if one does nothing: there is more and more leakage from the pipes, there is more and more defective meters, and out of date information in the customer and network databases.

Therefore, the value of the network efficiency at any moment is the combined result of the natural deterioration of the installations, and the procedures that have been put into place since their creation by the technical and the customer services departments to fight against this deterioration.

As an introduction let us focus first on three basic statements that bring about a new perspective:

Statement 1: About the causes of the losses.

The value of the losses from a system always results from two fundamental elements:

- The technical condition of the installations : age of the network, of the equipment, of the meters for instance
- How the installations have been managed in the past and how they are managed in the present.

To reduce the losses it is therefore necessary to do something about the installations (programme for rehabilitation and renewal) – what is currently admitted- but also about the management itself. This is the explanation of one of the more common error: many utility managers do believe that the only way to reduce their losses is to renew their installations and carry out substantial investments. But no sustainable results may be met without changing the management procedures themselves: implies full awareness from the managers and a management of change, the importance of which is often underestimated, if not completely denied.

Statement 2: About real and apparent losses.

Water Losses are divided into Real Losses (such as leakage) and Apparent Losses (such as under metering and unauthorised consumption).
The Water Balance, the application of which is promoted by IWA since Year 2000, facilitates both definition and calculation of the various kinds of loss. But here also we find the source of many usual misunderstanding and misuse of the concepts.

The first point is that the methods that are proposed are not always applicable and in some cases the accuracy of the apportionment of loss is very questionable; it may cause errors in terms of action planning. A lot has been done to manage real losses but much is still to be done to deal with apparent losses. IWA has created a special task force to work on that point (this is not the topic of this paper).

The second point is that the water balance just gives a picture of the situation at one given moment. Action planning is about how the balance will change when an action plan is carried out. Common mistakes are made by many practitioners, such as the incorrect perception that each time a leak is repaired physical loss is reduced by the volume saved and each time an illegal connection is regularised, the apparent loss will decrease by the related consumption. These two approaches are obviously wrong but there is little concern about the way these points should be taken into account.

In fact some other extremely important factors are often neglected by consultants and practitioners. The authors have defined some important concepts that should be taken into account in the design and implementation of any action planning model.

- *The Coefficient of Return of Anomalies (CRA)*: The name is self explanatory. When you replace "x" old meters, do not forget that those which have not been changed go on getting older, generating additional metering losses. When you repair "y" invisible leaks, how many new invisible leaks make their appearance after your intervention? And when you regularize "z" illegal connections, how many new illegal connections have been installed during the same period?
- *The Migratory Attribute of Losses (MCL)*: Have you thought that when you repair leaks in a district next to a low income area or next to an unmetered area for example, you are going to improve the pressure conditions and, indirectly, you are going to increase the non-metered and non-billed consumption of this area, generating additional apparent losses. Your loss indicator is not going to improve: you simply have transformed some real losses into apparent ones. This general phenomenon does not apply only to this example. More generally speaking any action may have side-effects and these side effects must be forecast and taken into account in the design of the action plan.
- *Time Factor and Visibility Threshold (TF):* When you repair one invisible leak or even 10 invisible leaks in a big system, the performance indicator, whatever it is, may not change. Starting from how many detected and repaired leaks will there be a visible impact on the performance indicator? Often the utility management loses patience and abandons the project even before the threshold is reached: this is a pity, for it is only after the detection threshold has been reached, that *"the snowball effect"*, which will ensure the success of the project, occurs.

Statement 3: About a holistic approach.

The total loss (Lt) from any water supply system is the sum of many components: real losses (Lr) and apparent losses (La) that can be divided themselves into many components as shown in figures 1 and 2.
$Lt = \sum Lr_i + \sum La_j$ (Equation 1)

During the implementation of an action plan each component will change (ΔL), negatively if there is some corrective actions and positively if nothing is done:

$$\Delta Lt = \sum \Delta Lr_i + \sum \Delta La_j \quad \text{(Equation 2)}$$

This is an algebraic formula. When all the components are not taken into account to design the action plan, the result may be surprising to the practitioner. The natural degradation of some term of the formula that had not been taken into account may have a higher impact than the action plan itself. For instance, if the practitioner only focuses on leak detection and repair, the real loss will be reduced but the total loss may continue to increase if there is a simultaneous increase in apparent losses.

Other example: if the utility renews 5% of its water meter each year, the impact on NRW may be lower than the impact of the aging of the 95% remaining meters.

The taking into account of these different phenomena and others that we cannot enumerate here, constitute what we call *the dynamics of losses, or the dynamic management of losses.* Many actions plans have failed for not having taken this into account. Taking this concept into account is one of the keys to success.

3. Review, assessment and water balance

All methods propose, before anything else, the establishment of a *hydraulic balance* separating the different kinds of loss, real or apparent. They can be presented either as a table (IWA format) or as a circular diagram as shown in figures 1 and 2. The circular representation enables one to visualize rapidly the proportion of the various loss and consumption components.

System Input Volume	Autorized consumption	Billed authorized consumption	Billed metered consumption (including water exported)	Revenue Water (or billed volumes)
			Billed unmetered consumption	
		Unbilled authorized consumption	Unbilled metered consumption	Non Revenue Water or (unbilled volumes)
			Unbilled unmetered consumption	
	Water losses	Apparent losses	Metering inaccuracies	
			Unauthorized consumption	
		Real losses	Transmission and distribution mains	
			Overflow or leakage of storage tanks	
			Service connections to meter	

Table 1 : IWA Water Balance

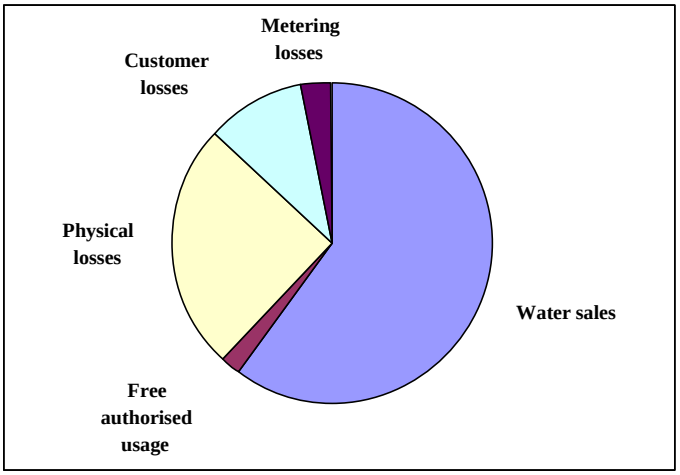


Figure 1 : Simplified Circular Water Balance Diagram

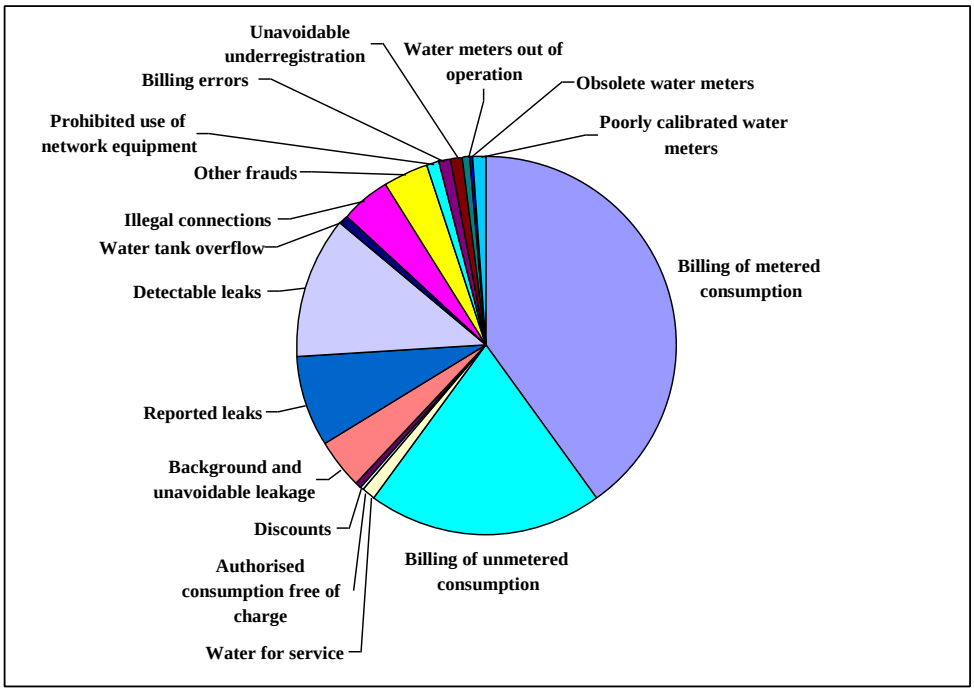


Figure 2 : Detailed Circular Water Balance Diagram

The establishment of a water balance is generally based on a rough appreciation of the apparent losses and a direct evaluation of real losses through the measurement of the minimum night flows (top-down approach and bottom-up approach). It generally gives good results when data are available and when it is possible to measure the minimum night flows. Unfortunately this method is not always applicable and this application may be very expensive.

When it is possible, the authors recommend evaluating both real and apparent losses with the same rigour. To do this, it is necessary to use statistical methods and field and laboratory operations as precise and rigorous as those used for the evaluation of the physical losses: consumption profile of users, study of ageing of meters, determination of the weighted mean error per type of meter, determination of general under-registration of all the meters, definition of segments of consumers at risk, targeted field surveys etc.

Anyway, the NRW audit and the establishment of the water balance is a prerequisite for action planning.

The detailed NRW audit and the establishment of the water balance generally consist of two levels:

1. The preliminary diagnosis that is conducted by the analysis of data available in the water utility
2. The final diagnosis that requires complementary study (field or laboratory) in order to refine the preliminary diagnosis.

With regards to the final diagnosis it must be based on sample or pilot surveys with the following objectives:

- testing a method to reduce the considered type of loss
- testing human and material resources
- calculating indicators
- measuring impact, time factor and visibility threshold
- assessing rate of returns of anomalies
- making cost benefit analysis

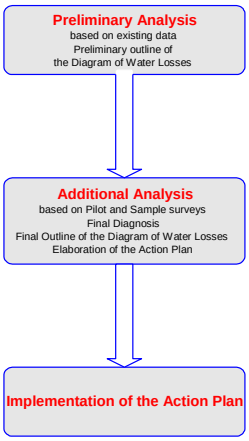


Figure 3 : From the preliminary analysis to the action plan

An action plan for the reduction of losses must never be constructed without having undertaken as detailed a diagnosis as possible beforehand. Each component of the loss needs to be tested. One could indeed quote many examples of action plans that have failed for the lack of global vision of the loss

processes. As said before, the cause is simple: some actions, however logical, simply do not give the expected results because the gains that they are producing are hidden by increased losses in other domains. Whatever the case, the overall review, quantified through the Water Balance, is never a waste of time. This statement needs to be repeated because too many utilities start action plans without any global vision: It is a frequent cause of failure.

4. The design of the action plan

The objective of the action plan is to counterbalance the entropic tendency of the losses to increase. The audit and action plan will necessarily include seven constituents: to neglect one of them, either for the audit or for the action plan, would have harmful results on the implementation of the plan. We will be even more categorical: it would be a nearly automatic cause of failure. To be convinced just have a look at equation 2.

The structure of the circular water balance defines the structuring of the audit and that of the action plan.:

- Part 1 : Bulk Metering
- Part 2: Customer Management and Water Sales.
- Part 3: Service Water and other Free Distributions.
- Part 4: Real Losses.
- Part 5: Commercial (Apparent) Losses.
- Part 6: Metering (Apparent) Losses.
- Part 7 : Project Management and Change Management

Table 2 : The seven components of an action plan for reduction of loss

The first six components of the Audit and action plan correspond very precisely to the Circular Balance itself and the five sectors that make it up.

The objective of the first three parts is to know, as precisely as possible, the global value of the loss. They also aim at improving the normal operational procedures of the utility. Whatever program is used for the reduction of the losses it will only produce permanent results if it is accompanied by a real effort to improve the operating conditions of the company (organization, procedures, human resources, etc.), such as:

1. A program for the control and optimisation of the macro metering of the volumes distributed.
2. A program for the optimisation of the customer meter reading and billing activity.
3. A program for the control and the reduction of the authorised unbilled consumptions.

The objective of the following three parts is to reduce each major component of the loss:

4. Program for the detection and the reduction of the physical losses: detection and repair of the visible and invisible leaks, renewal of the network, control of reservoir overflows.
5. Programs for the reduction of under metering (meter park management)
6. Programs for the detection and reduction of the commercial losses (customer services management)

Each program consists in a set of specific actions related to the various sectors of figure 2. Most practitioners know these actions; they are not described in this paper which mainly aims at describing the best way to carry them out in the frame of a holistic and successful approach. It is fundamental in the elaboration of these various programs to take into account *the dynamic approach to the losses*.

7. Project management and Change management

The seventh component is by far the most important component. Firstly at the level of the audit: in analysing the functioning and the organisation of the utility in all its aspects, one will understand the causes for the present level of losses and its evolution in the course of the past years. Secondly at the stage of the implementation it will be responsible for the success of the plan and the sustainability of its results. The sections ahead are dedicated to these topics.

5. The most frequent causes for failure and the keys to success

It is a well known saying: "you learn more from your setbacks than you do from your successes". The authors have applied it; the detailed analysis of many action plans for the reduction of losses has enabled them to detect the most frequent causes for failure. There is no room here to comment on these individually, but it must be remembered that just one of these causes is enough to stop a plan from succeeding. These causes for failure are the direct consequence of the non-application of the principles described above.

1. Partial implementation of the plan: working on one component only, for instance.
2. Initial diagnosis too perfunctory: Too many diagnoses are based on preconception instead of experimentation.
3. Action plan poorly elaborated: migratory attributes of losses have not been taken into account.
4. Non mobilisation of necessary human and financial resources.
5. Lack of coordination between the components of the plan
6. Under-estimation of the difficulties.
7. Under-estimation of the time factor.

Table 3 : The 7 most frequent source of failure

On the other hand, the keys to success are as follows: all of them were implemented in the successful plans that have been analysed.

1. Real management of the project: project manager, clear quantified objectives, time schedule, appropriate resources, proper follow-up and monitoring.
2. Management Committee ensuring the coordination within the Utility.
3. Appropriate human and financial resources.
4. Modern high performance techniques and tools.
5. Tools for monitoring progress indicators and performance indicators by sector of activity.
6. Conscious management of change
7. Real desire of the top management for success of the project.

Table 4 : The 7 keys to success

6. Implementation of the action plan

Let us focus now on the way to avoid the causes for failure and use the keys for success. The analysis of the causes for success and failure shows that the seven components of the plan have different natures:
- Components 1 to 3 refer to the improvement of the current operation of the utility
- Components 4 to 6 refer to the action plan itself
- Component 7 refer to the project management and change management dimensions of the project.

The analysis of the causes for failure shows that Part 7 (Organisation) is the more important for both implementation and success of the programme. Part 7 is responsible for:
- the implementation of the programme
- the sustainability of the results
- the change management put into place

Most practitioners know a lot about the first six operational components of the action plan and many papers are presented on this topic in most conferences. Therefore the stress is put hereafter on the nonoperational matters that are necessary to make action planning successful; project management and change management.

7. Project Management

Many utility managers believe that NRW will reduce if each department does its work properly. A current mistake is to say that each department is responsible for a part of the plan, i.e. the distribution network department is in charge of the leak detection programme and the customer department is in charge of replacing meters and detecting illegal consumption. However, due to the migratory nature of the losses it will not work if there is no integrated coordination.

To avoid this situation it is necessary to have a real project management structure. What is real project management? It is the same as for any project, but there is also some specificity in the case of action planning to control for non-revenue water.

A genuine Project Management

- *Objective:* Too often the objective is only qualitative: reducing the loss. This is not enough: the objective must be quantified: for instance reducing the total loss from 30% to 25% of the water input. If the Utility believes it is impossible to fix so precise targets it simply shows that the audit has not been properly carried out. The plan will probably fail.
- *Project manager:* There is a need for a single project manager as the champion of the project. In failed action plans there were many people in charge and each one was convinced that the others were responsible for the global failure.
- *Detailed time schedule:* A detailed time schedule must be prepared for each action of each component of the action plan. The concept of critical path is particularly important in that sort of project.
- *Human resources and material resources:* Human and material resources must be planned at the design stage of the project. Very often the financial resources are not available (because they have not been properly forecasted) and the utility concentrates the resources on one or two sub- projects that are considered as priority. Generally, it is a major mistake that proves that there is no understanding of what a comprehensive NRW action plan is.
- *Monitoring progress:* As for any project, it is necessary to produce periodical reports showing the progress of the various components of the project. If it has been decided to replace 25km of pipes and

10.000 water meters and to make a customers' survey covering 50% of the city for instance the progress will be evaluated through progress indicators monthly or quarterly calculated as a percentage of each target.
- *Monitoring results:* This is already something more specific for NRW action planning. It often happens that the Utility has finished the forecast investments and works as scheduled and that the initial NRW target has not been met. In the worst cases – unfortunately those are not so uncommon - there is no improvement at all in the NRW value. This is probably due to a poor analysis of the dynamics of losses: we can imagine for instance that the plan has focused on real losses only and that most real losses have been converted into apparent losses, with no profit at all for the utility. To avoid such a situation it is absolutely necessary to have a proper follow-up of the performance indicators and to analyse what the correlation between performance indicators and progress indicators is.

Specificity of the NRW project management

An NRW project has a lot of specificity that are not usual for other kinds of project:

At first, NRW project is not an external project that can be fully outsourced. Following Figure 4 shows a typical organisation chart and what the involvement of each unit of the utility is. All departments are involved, and must be involved, in the implementation of the action plan.

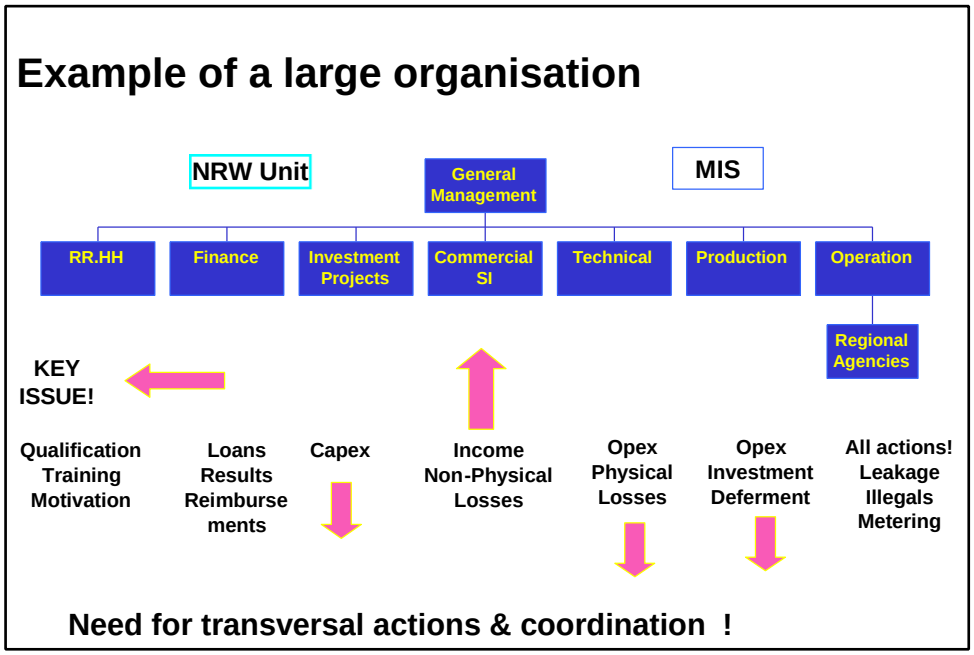


Figure 4 : NRW in a large water utility

This chart also shows that:

- Human resources, including qualification, training and motivation are a key issue - There is a need for transversal actions and coordination.
- The NRW Unit needs to work at the level of the General Management of the Utility; it should work as a NRW Steering Committee.
- In addition, there is a need for an appropriate Management Information System (MIS) that will give all useful data including progress *and* performance indicators. It is difficult to manage an action plan in a large water utility without such a MIS.

There are other specificities for that kind of project:

- The project is implemented by a multiple structure (the water utility) in which each department also has its own annual objectives: it may create some internal conflicts that need to be solved.
- The utility is at the same time the main actor of the action plan and its target in terms of change management. The results will not be sustainable if the utility does not change its own culture.

These two specificities are two more reasons to promote the creation of a NRW Steering Committee.

The NRW Steering Committee

The NRW Steering Committee generally consists of the NRW Coordinator (or NRW Project Manager), the Heads of the main Departments, invited corporate staff depending on the main items of the agenda and external auditor (sometimes). The use of an external auditor is recommended, firstly because this unit is independent and it is easier for the unit to propose solutions to internal conflicts, secondly because the unit is experienced in NRW action plan, which is sometimes not the case for the other members of the Committee.

In monthly or quarterly meetings the main tasks of the NRW Steering Committee are the following:
(i) analysing the coordinator's reports, (ii) verifying that the last committee's decision have been fully implemented, (iii) taking current decisions, (iv) re-orienting some actions when necessary, (v) addressing the internal conflicts and (vi) being in charge of managing the Change scenario.

NRW Simulation Software

Being able to reorienting an action plan when necessary is one of the main key for success. It is very useful, not to say indispensable, that the manager of the plan has at his disposal computer tools allowing

him to evaluate at any moment the components of the loss (simulation of the water balance) and to compare the actual results to the expected results of the various actions (simulation of the Plan itself). A NRW simulation model aggregates the forecast results of each action and compares the forecast NRW indicators to the real NRW indicator measured in the field. To calculate the impact of each action on NRW indicator it is necessary to take into account the direct positive impact of this action, the natural deterioration in the same field, and some parameters related to the dynamics of loss such as the rate of return of the anomalies.

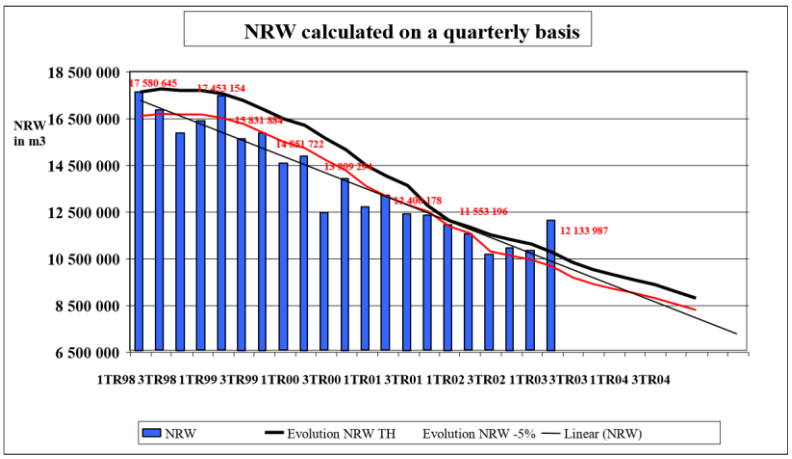


Figure 5 : NRW simulation in a project including more than 10 components (Source: IWA 2004 – Marrakech – The Casablanca Case)

As in any simulation software, the NRW simulation software needs to be calibrated. The calibration is often based on the result of the initial audit but it can be improved during the first stage of the action plan.

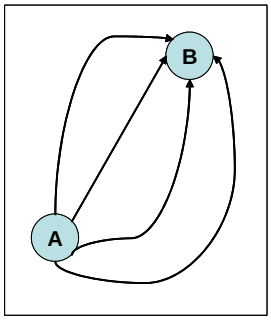
Operational comment: In many cases, special reports are established to follow up the action plan and it appears that the data are not consistent with the overall corporate information system. It is of paramount importance in the monitoring of an action plan to check the consistency between the NRW reporting and the other softwares used by the utility, such as Customers'database & Billing system (CIS).

8. Change Management

As far as losses are concerned, the objective is passing from a level of loss A ("natural" taking into account the current mode of management) to another level of loss B (reached thanks to the Action Plan).

The passage from Level A to Level B will involve many aspects, technical, human, organisational or even institutional ones. It is *the conscious management of this change* which will guarantee the success of the plan, but also and above all the sustainability of the results obtained. There are many paths from A to B.

The authors have analyzed many plans that have failed. In all these plans, the change component had never been taken into account seriously. In fact, there was a diffuse awareness that many things had to be changed but it was considered as a somewhat philosophical concern: the management thought that the use of new tools and the definition of new procedures were sufficient to automatically change mental attitudes and corporate culture.



This is a very basic mistake: the change must be analysed as a component of the action plan itself. As for any change approach, there is a need for understanding change, planning change, implementing change and consolidating change.

"Understanding Change" must be part of the NRW audit itself; each utility department needs (i) to understand why the change is necessary, (ii) to analyse what are the causes and the sources of change and (iii) to categorize

the various needed type of change.

Change must be planned as the other operational components of the global NRW plan. It is necessary to focus on specific goals, to identify the demand for change, and to select the essential change necessary to meet the final NRW target. It is necessary to evaluate the complexity of change and in particular to anticipate side-effects and resistance to change.

The main components of change are an appropriate communication, an appropriate training policy, the assignment of responsibilities and the development of commitment at all levels. All these actions will obviously change the corporate culture, albeit gradually. Only though a management philosophy that is implemented by the Water Utility's top management team can this corporate culture develop and proliferate.

Finally the Change needs to be consolidated. Progress must be monitored, assumption must be continuously reviewed and change management skills must be continuously assessed. Many approaches and tools are used to define a change policy, such as: Enterprise Engineering Assessment (M.O.S.T. approach, management operation staff and technology); Creation of a Value Stream based Change Programme; and a Quality programme (ISO 9001-2000 and ISO 24500).

9. Action Planning Model

Current analysis shows that the seventh component of the 7-part action plan is of paramount importance for the success of the other components and for the sustainability of the plan and results.
Finally, the analyses of failed and successful plans show that that the three dimensions of interest in NRW action planning are as follows:

- *The dimension relating to change management.* This first dimension looks at the readiness or willingness of the water utility to tackle the NRW project. Issues such as institutional and stakeholder support, a clear mandate, an established project strategy and a well-chosen project management team all come into play.
- *The dimension relating to project management.* Once the utility has accepted, and is committed, to the implementation of a project to manage non-revenue water, the onus then falls on the management team entrusted with the project. Genuine project management requires a project champion, quantified objectives, time scheduling, resource availability, and the correct tools and techniques, for the project to be successful.
- *The operational dimension.* This third dimension looks at the creation of a present and target water balance for a water utility, and the technical and operational issues that are required to transgress from the present to the target water balance. The basis for this operational dimension is an innovative concept described by the authors as the 'dynamic management of losses'. The project team (dimension 2) supported by the mandate provided by the entity (dimension 1) has to implement an action plan in the face of various opposing forces.

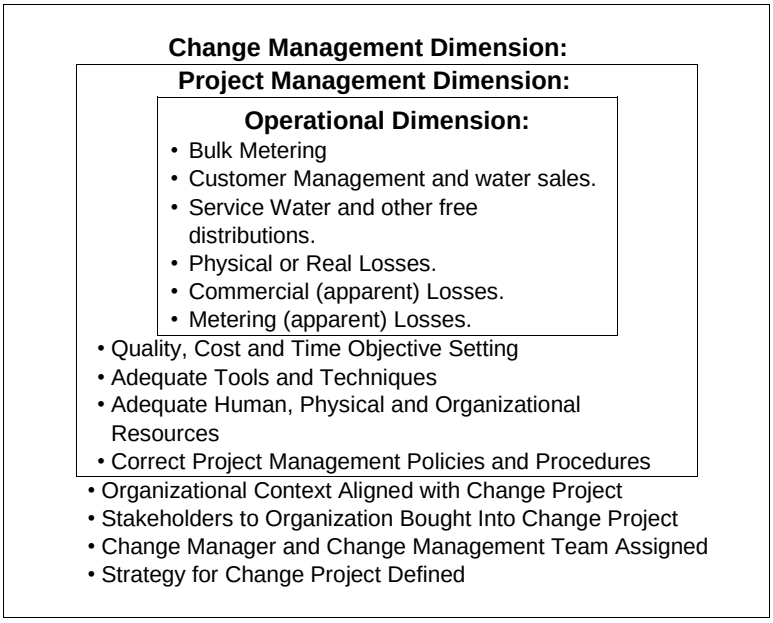


Figure 6 : Action Planning Model for NRW Reduction and Control

The reader will understand that the approach that is proposed here is quite different of the usual one. In fact it is just the opposite: the main target is a global and sustainable change and operational measures are just a mean - necessary but not sufficient - to meet this target.

The authors hope that these few considerations will complete the methods used at present and will contribute to bring them nearer to the real needs of the water utilities. In their next paper, they plan to give a specific focus on the essential dimension relating to change management in water utilities.