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Sustainability evaluation of pipe asset management strategies

John C. Matthews[a,*], Kalyan Piratla[b], and Dan D. Koo[c]

[a]Pure Technologies, 7231 Palmetto Dr., Baton Rouge, LA, 70808, USA
[b]Clemson University, 109 Lowry Hall, Clemson, SC, 29634, USA
[c]IUPUI, 799 W. Michigan St. ET 314J, Indianapolis, IN, 46202, USA

Abstract

The consequences associated with pipe failures can be widespread impacting service, while potentially causing damage, affecting traffic, and contaminating water. Recently the visibility of pipe failures has increased with social media and 24-hour news coverage. In response, many utilities have adapted pipe asset management strategies to reduce failures. Also, many technologies have emerged that allow for a more proactive pipe asset management. As sustainability has become a focus for many organizations including utilities, the question becomes which pipe asset management strategy is most sustainable. The purpose of this paper is to evaluate three pipe asset management strategies for sustainability using Envision®. The strategies include: a reactive run-to-failure and then replace; a preemptive replacement prior to failure based on assumed condition; and a balanced approach of active condition assessment and action based on the known condition. Envision® will be used to evaluate each approach to determine its sustainability rating.

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Keywords: Sustainability Evaluation; Pipe Asset Management; Pipe Condition Assessment

1. Introduction

Water utilities provide service to their customers at a substantial discount typically as rates are not indicative of the actual cost it takes to provide water service. There are many reasons for that which are not the focus of this paper, but the impact is that maintenance and replacement rates lag and failures rates increase. This puts water

* Corresponding author. Tel.: +1-318-224-0141
E-mail address: john.matthews@puretechltd.com

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utilities in a difficult place of having to manage larger portion of their systems with emergency repairs. While this seems inherently unsustainable, many are unaware of better options given the financial shortfalls. The purpose of this paper is to evaluate three strategies for sustainability using the Envision® pre-assessment checklist [1] to determine if there is a better way to manage pipes. The strategies are discussed more below and include: a reactive run-to-failure and then replace, which is common for under-funded utilities; a preemptive replacement prior to failure based on assumed condition, which happens when funds are available, but pipe condition is not; and a balanced approach of active condition assessment and rehabilitation action based on the known condition, which is a common strategy for proactive water pipe management.

2. Sustainability Evaluation

The sustainability evaluation was performed using the Envision® pre-assessment checklist [1] which is intended to help incorporate sustainability in the planning phase of a project. This checklist assigns credits or points to a plan based on the number of yes answers to a series of questions. These questions are broken down into five categories, namely: (1) quality of life; (2) leadership; (3) resource allocation; (4) natural world; and (5) climate and risk. There are a total of 55 credits in the checklist with each credit containing an intent, metric, and between one and seven assessment items. The intent describes the purpose of the credit and how it contributes to sustainability. The metric explains how the project team can be successful in meeting the intent of the credit. The assessment items determine if the project meets the intent for that credit.

3. Pipe Management Strategies

The three pipe management strategies evaluated with Envision® are discussed below.

3.1. Run-To-Failure

Running pipes to failure is typically only recommended when failure consequences are quite low. Unfortunately this happens more often than recommended due to financial shortfalls. In an example case, a 12-in cast iron pipe that breaks in the middle of the night would require an emergency repair without significant planning, which is costly and disruptive. For this evaluation, assumptions were made about the types of planning that go into an emergency pipe repairs, but it was clear that the main sustainable advantages the other two strategies have over the run-to-failure scenario is the inherent planning that goes into those options. It was assumed that little planning and design occur before an emergency repair.

3.2. Preemptive Replacement

Preemptive replacement based on pipe parameters is very common and can reduce the impact and likelihood of failures. The downside is that typical pipe replacement can be highly disruptive and if replacement is only based on pipe parameters such as age and material and not the actual condition, some pipes will be replaced before they should while they still have remaining life and value. For example, a cast iron main that is designed for 50 years may still have useful life at 50 years, therefore preemptive replacement may mean replacing the pipe before it needs to be. It was assumed that preemptive replacement would have a significant amount of planning and design when compared to emergency repairs, but that replacing the main would be more disruptive than rehabilitating the pipe, which is considered in scenario #3.

3.3. Balanced Approach

When proactive condition assessment is used, the actual condition of a pipe can be factored into the repair decision. This helps to prevent the replacement of pipes with significant remaining useful life. After a pipe is inspected, the actual conditions are then known, and repair decisions and timing can be made that maximize remaining life, while restoring the pipe to a proper condition. Rehabilitation methods such as liners that minimize disruption by avoiding full-length excavation while adding structural integrity to the pipe are preferred when the conditions allow and costs are beneficial. This is a significant improvement over simply replacing the pipe once it hits a certain age, which was covered in the previous scenario.

4. Envision Sustainability Evaluation

The results of the Envision® sustainability are discussed below in more detail. The results from the evaluation are presented in Tables 1-5 which provide the answers to all 144 questions in the checklist for all three scenarios. The tables are broken up into focus areas, namely: Table 1 – Quality of Life; Table 2 – Leadership; Table 3 – Resource Allocation; Table 4 – Natural World; and Table 5 – Climate and Risk. The primary differences for each area are discussed where applicable. The authors provided the answers to the questions based on their industry experience.

4.1. Quality of Life

The results for the Quality of Life evaluation are shown in Table 1 and summarized in Figure 1. While 10 of the questions could not be easily associated with any scenario, 16 were easily associated with the balanced approach, 10 with preemptive replacement, and only three for run-to-failure. The primary benefits of the balanced approach over preemptive replacement were related to minimizing disruption (questions 2.2 and 2.4). Preemptive replacement was much more sustainable than run-to-failure in multiple areas due to design and planning (questions 1.1, 2.6, 3.2, etc.).

Table 1. Answers to Quality of Life questions.

No.	Questions	#1*	#2*	#3*
1.1a	Are the relevant community needs, goals and issues being addressed in the project?	Y	N	Y
1.1b	Are the potentially negative impacts of the project on the host communities been reduced or eliminated?	N	Y	Y
1.1c	Has the design received broad community endorsement from community leaders and stakeholder groups?	N	Y	Y
1.2a	Will the project contribute significantly to local employment?	N	N	N
1.2b	Will the project make a significant increase in local productivity?	N	N	N
1.2c	Will the project make the community more attractive to people and businesses?	Y	Y	Y
1.3a	Does the project team intend to hire and train a substantial number of local workers?	N	N	N
1.3b	Does the project team intend to use a substantial number of local suppliers and specialty firms?	N	N	N
1.3c	Will the project make a substantial improvement in local capacity and competitiveness?	N	N	N
2.1	Does the owner and team intend to institute new standards to address additional risks and exposures?	N	N	N
2.2	Will the project reduce noise and vibration to levels below local permissible levels during construction?	N	N	Y
2.3	Will the project be designed to reduce excessive lighting, prevent light spillage and preserve the night sky?	N	N	N
2.4a	Will the project provide good, safe access to adjacent facilities, amenities and transportation hubs?	N	N	Y
2.4b	Will the design take into consideration the expected traffic to improve overall mobility and efficiency?	N	N	Y
2.4c	Has the team coordinated the design with other infrastructure assets to reduce traffic and improve liability?	N	Y	Y
2.5a	Will the project be within walking distance of accessible multi-modal transportation?	N	N	N
2.5b	Through its design, will the project encourage the use of transit and/or non-motorized transportation?	N	N	N
2.6a	Will the project contain the appropriate signage for safety and wayfinding in and around the site?	N	Y	Y
2.6b	Will the project address safety and accessibility in and around the site for users and emergency personnel?	Y	Y	Y
2.6c	Will the project extend accessibility and intuitive signage to protect nearby sensitive sites or neighborhoods?	N	Y	Y
3.1a	Will the project minimize negative impacts on historic and cultural resources?	N	N	Y
3.1b	Will the project be designed so that it fully preserves historic/cultural resources on or near the project site?	N	Y	Y
3.2a	Will the project be designed in a way that preserves views and local character?	N	N	Y
3.2b	Will the project be designed to improve local character through preservation or restorative actions?	N	Y	Y
3.3a	Will the project make meaningful enhancements to public space?	N	N	N
3.3b	Will the project result in a substantial restoration to public space?	N	Y	Y

*#1-Run-to-failure; #2-Premptive replacement; #3-Balanced approach

4.2. Leadership

The results for the Leadership evaluation are shown in Table 2 and summarized in Figure 2. While four of the questions could not be easily associated with any scenario, 15 were easily associated with the balanced approach, 5 with preemptive replacement, and none for run-to-failure. The primary benefits of the balanced approach over preemptive replacement were related to the inherent sustainable benefits of rehabilitation versus replacement (questions 1.1, 1.3, 2.2, etc.). Preemptive replacement was much more sustainable than run-to-failure in multiple areas again due to design and planning (questions 1.3, 1.4, 3.2, etc.).

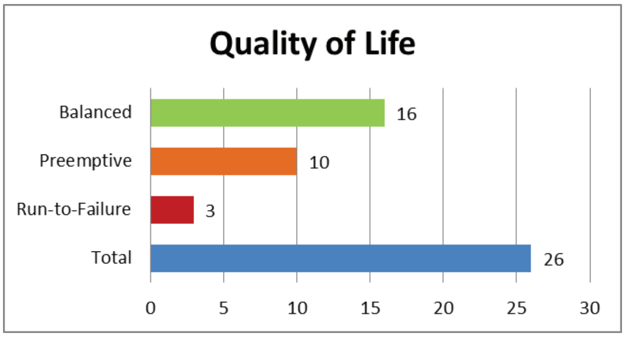

Figure 1. Quality of Life summary.

Table 2. Answers to Leadership questions.

No.	Questions	#1*	#2*	#3*
1.1a	Has the project team issued public statements stating their commitment to sustainability?	N	N	Y
1.1b	Is the project team's commitment to sustainability backed up by examples of actions taken or to be taken?	N	N	Y
1.1c	Do these commitments demonstrate sufficiently that sustainability is a core value of the project team?	N	N	N
1.2	Does the team intend to establish a workable sustainability management system?	N	N	N
1.3a	Are the project owner and team considering the performance relationship of this project to other elements?	N	Y	Y
1.3b	Will the project owner and team establish a collaborative relationship to achieve sustainable performance?	N	N	Y
1.3c	Will the project owner and team institute a whole systems design to maximize sustainable performance?	N	N	Y
1.4a	Will key stakeholders in the project be identified and lines of communication established?	N	Y	Y
1.4b	Does the project team plan to engage with stakeholders and solicit stakeholder feedback?	N	Y	Y
1.4c	Will the team establish a stakeholder involvement process to involve the public in decision-making?	N	N	Y
2.1	Will the project team establish a program to make use of unwanted by-products and materials on the project?	N	N	N
2.2a	Will the project team seek to optimize sustainable performance at the infrastructure component level?	N	N	Y
2.2b	Will the project team seek to optimize sustainable performance by designing as an integrated system?	N	N	Y
2.2c	Will the project be planned and designed so that its operation are fully integrated in the community?	N	N	Y
3.1a	Will the project have a plan for long term monitoring and maintenance?	N	N	Y
3.1b	Will that plan be sufficiently comprehensive, covering all aspects of long-term monitoring and maintenance?	N	N	Y
3.2a	Will an assessment of applicable regulations be done, identifying those counter to project objectives?	N	Y	Y
3.2b	Do the owner and the project team intend to approach decision-makers to resolve conflicts?	N	N	N
3.3	Will the project be designed in ways that extend substantially the useful life of the project?	N	Y	Y

*#1-Run-to-failure; #2-Premptive replacement; #3-Balanced approach

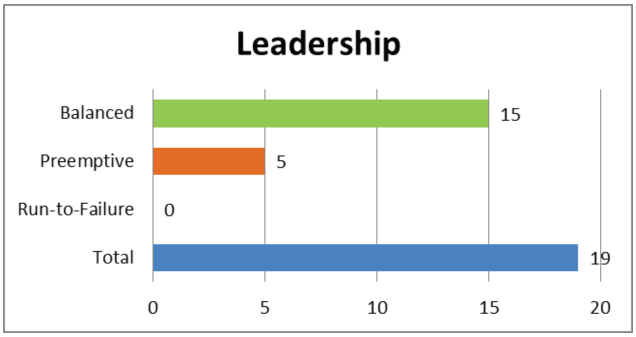

Figure 2. Leadership summary.

4.3. Resource Allocation

The results for the Resource Allocation evaluation are shown in Table 3 and summarized in Table 3. While 23 of the questions could not be easily associated with any scenario, 18 were easily associated with the balanced approach, 12 with preemptive replacement, and only two for run-to-failure. The primary benefits of the balanced approach over preemptive replacement were related to assessment and monitoring (questions 2.3 and 3.3). Preemptive replacement was much more sustainable than run-to-failure in multiple areas due again to design and planning (questions 1.5, 1.6, 3.1, etc.).

Table 3. Answers to Resource Allocation questions.

No.	Questions	#1*	#2*	#3*
1.1a	Does the team plan to conduct an assessment of the embodied energy of key materials over the project life?	N	N	N
1.1b	Will the project achieve at least a 10% reduction in net embodied energy over the life of the project?	N	N	N
1.2a	Will the team establish a preference for using suppliers that have strong sustainable policies and practices?	N	N	N
1.2b	Will the project team establish a sound and viable sustainable procurement program?	N	N	N
1.2c	Does the team intend to source at least 15% of project materials, equipment, etc from these companies?	N	N	N
1.3a	Will the team consider the appropriate reuse of existing materials and incorporate them into the project?	N	N	Y
1.3b	Will the project team specify that at least 5% of materials with recycled content be used on the project?	N	N	N
1.4a	Will the project team work to identify local/regional sources of materials?	N	N	N
1.4b	Are at least 30% of project materials locally sourced?	N	N	N
1.5a	Will the team identify potential recycling and reuse destinations for construction waste generated on site?	N	Y	Y
1.5b	Will the team develop a waste management plan to decrease waste from landfills and incinerators?	N	Y	Y
1.5c	Will the project divert at least 25% of project waste from landfills?	N	N	N
1.6a	Will the project be designed to balance cut and fill to reduce the amount of excavated material taken off site?	Y	Y	Y
1.6b	When necessary, will the project team taken steps to identify local sources/receivers of excavated material?	N	Y	Y
1.6c	Will the project reuse at least 30% of suitable excavated material onsite?	Y	Y	Y
1.7a	Will the team assess whether materials specified can be easily recycled or reused after the project has ended?	N	N	N
1.7b	Will the project be designed so that at least 15% of project materials can be easily separated for recycling?	N	N	N
1.7c	Will the team incorporate methods for increasing the likelihood of materials recycling?	N	N	N
2.1a	Will the team conduct reviews to identify options for reducing energy consumption during operations?	N	N	N
2.1b	Will the team conduct feasibility studies to determine the most effective methods for energy reduction?	N	N	N
2.1c	Is the project expected to achieve at least a 10% reduction in energy consumption?	N	N	N
2.2a	Will the owner and team identify options to meet operational energy needs through renewable energy?	N	N	N
2.2b	Will the project meet at least 25% of its energy needs through renewable energy?	N	N	N
2.3a	Does the owner and team intend to conduct an independent commissioning of the project's energy systems?	N	N	N
2.3b	Will the team assemble the necessary information needed to train operations workers?	N	N	Y
2.3c	Will the design incorporate advanced monitoring systems to enable more efficient operations?	N	N	Y
3.1a	Will the project team assess project water requirements?	N	Y	Y
3.1b	Does the team plan to conduct a comprehensive assessment of the project's long-term impacts on water?	N	Y	Y
3.1c	Will the project only access water that can be replenished in both quantity and quality?	N	N	N
3.1d	Will the project consider the impacts of fresh water withdrawal on receiving waters?	N	N	N
3.1e	Will the project discharge into receiving waters meet quality requirements for high value aquatic species?	N	Y	Y
3.1f	Will the project achieve a net-zero impact on water supply quantity and quality?	N	Y	Y
3.1g	Will the project restore the quantity and quality of fresh water surface and groundwater supplies?	N	N	N
3.2a	Will the project team conduct planning or design reviews to identify potable water reduction strategies?	N	Y	Y
3.2b	Will the team conduct feasibility analysis to determine the most effective methods for water reduction?	N	Y	Y
3.2c	Will the project achieve at least a 25% reduction in potable water consumption?	N	N	N
3.2d	Will the project result in a net positive generation of water as a result of on-site purification or treatment?	N	N	N
3.3a	Will the owner and team conduct an independent monitoring of the project's water systems?	N	N	Y
3.3b	Will the project design incorporate the means to monitor water performance during operations?	N	Y	Y
3.3c	Will the project integrate long-term operations and monitoring to mitigate negative impacts?	N	N	Y
3.3d	Will specific strategies be put in place to utilize monitoring and leak detection?	N	N	Y

*#1-Run-to-failure; #2-Premptive replacement; #3-Balanced approach

4.4. Natural World

The results for the Natural World evaluation are shown in Table 4 and summarized in Figure 4. While 19 of the questions could not be easily associated with any scenario, 28 were easily associated with the balanced approach, 26 with preemptive replacement, and 21 with run-to-failure. The only benefits of the balanced approach over preemptive replacement were related to non-disruptive repairs (question 1.4). The only benefits of preemptive replacement over run-to-failure were related to design and planning (questions 1.5 and 2.2).

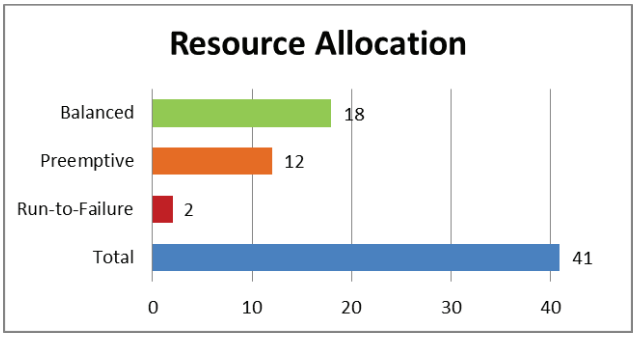

Figure 3. Resource Allocation summary.

Table 4. Answers to Natural World questions.

No.	Questions	#1*	#2*	#3*
1.1a	Will the project team take steps to identify and document areas of prime habitat near or on the site?	N	N	N
1.1b	Will the project avoid development on land that is judged to be prime habitat?	Y	Y	Y
1.1c	Will the project establish a minimum 300 ft. natural buffer zone around all areas deemed prime habitat?	N	N	N
1.1d	Will the project significantly increase the area of prime habitat through habitat restoration?	N	N	N
1.1e	Will the project improve habitat connectivity by linking habitats?	N	N	N
1.2a	Will the project avoid development on wetlands, shorelines, and waterbodies?	Y	Y	Y
1.2b	Will the project maintain soil protection zones (VSPV) around all wetlands, shorelines, and waterbodies?	N	Y	Y
1.2c	Will the project restore degraded existing buffer zones to a natural state?	N	N	N
1.3	Will this project avoid development on land designated as prime farmland?	Y	Y	Y
1.4a	Will the project team identify and address the impacts of sensitive or adverse geology?	N	Y	Y
1.4b	Will the project be designed to reduce the risk of damage to sensitive geology?	N	N	Y
1.4c	Will the project be designed to reduce the risk of damage from adverse geology?	N	N	Y
1.5a	Will the project avoid or limit development within the design frequency floodplain?	N	N	N
1.5b	Will the project maintain pre-development floodplain infiltration and water quality?	Y	Y	Y
1.5c	Will the project design incorporate a flood emergency operations and/or evacuation plan?	N	Y	Y
1.5d	Will the project maintain or enhance riparian and aquatic habitat, including aquatic habitat connectivity?	Y	Y	Y
1.5e	Will the project maintain sediment transport?	Y	Y	Y
1.5f	Does the project team intend to modify or remove infrastructure subject to frequent damage by floods?	Y	Y	Y
1.6a	Will the project team use best management practices to manage erosion and prevent landslides?	Y	Y	Y
1.6b	Will the project team minimize or avoid all development on or disruption to steep slopes?	Y	Y	Y
1.7a	Will the project team consider how the project can conserve undeveloped land?	Y	Y	Y
1.7b	Will at least 25% of the project development be located on previously developed sites?	Y	Y	Y
2.1a	Will the project be designed to reduce storm runoff to pre-development conditions?	Y	Y	Y
2.1b	Will the project be designed to significantly improve water storage capacity?	N	N	N
2.2a	Will operational policies be put in place to control and reduce the application of fertilizers and pesticides?	Y	Y	Y
2.2b	Will the project include runoff controls to minimize contamination of ground and surface water?	N	Y	Y
2.2c	Will the project team select landscaping plants to minimize the need for fertilizer or pesticides?	N	N	N
2.2d	Will the team select fertilizers and pesticides with low-toxicity and bioavailability?	N	N	N
2.2e	Will the project be designed to eliminate the need for pesticides or fertilizers?	Y	Y	Y
2.3a	Will the project team conduct or acquire hydrologic delineation studies?	N	N	N
2.3b	Will spill and leak prevention and response plans and design be incorporated into the design?	Y	Y	Y
2.3c	Will the project design reduce or eliminate potentially polluting substances from the project?	Y	Y	Y
2.3d	Will the team seek to reduce future contamination by cleaning up areas and instituting land use controls?	N	N	N
3.1a	Will the project team identify existing habitats on and near the project site?	N	N	N
3.1b	Will the project protect existing habitats?	N	Y	Y
3.1c	Will the project increase the quality or quantity of existing habitat?	N	N	N
3.1d	Will the project preserve, or improve, wildlife movement corridors?	Y	Y	Y
3.2a	Will the project team specify locally appropriate and non-invasive plants on the site?	N	N	N
3.2b	Will the project team implement a comprehensive plan to identify, control, and eliminate invasive species?	N	N	N
3.2c	Will the team implement a comprehensive plan to mitigate the future encroachment of invasive species?	N	N	N
3.3a	Will the project restore 100% of soils disturbed during construction?	Y	Y	Y
3.3b	Will the project restore 100% of soils disturbed by previous development?	N	N	N
3.4a	Will the project maintain or enhance hydrologic connection?	N	N	N

3.4b	Will the project maintain or enhance water quality?	Y	Y	Y
3.4c	Will the project maintain or enhance habitat?	Y	Y	Y
3.4d	Will the project maintain or restore sediment transport?	N	N	N
3.4e	Will wetlands and surface water be maintained to have a fully functioning aquatic and riparian ecosystem?	Y	Y	Y

*#1-Run-to-failure; #2-Premptive replacement; #3-Balanced approach

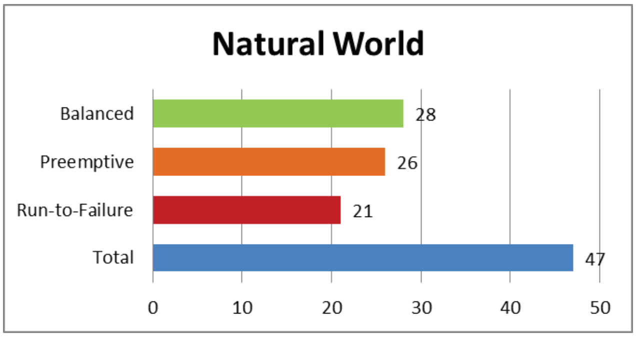

Figure 4. Natural World summary.

4.5. Climate and Risk

The results for the Climate and Risk evaluation are shown in Table 5 and summarized in Figure 5. While five of the questions could not be easily associated with any scenario, six were easily associated with the balanced approach, five with preemptive replacement, and none for run-to-failure. The primary benefits of the balanced approach over preemptive replacement were related to minimizing dust during construction (question 1.2). Preemptive replacement was much more sustainable than run-to-failure in multiple areas again due to design and planning (questions 2.2, 2.3, and 2.4).

Table 5. Answers to Quality of Life questions.

No.	Questions	#1*	#2*	#3*
1.1a	Will a life-cycle carbon assessment be conducted on the project?	N	N	N
1.1b	Based on that assessment, will the project be designed to reduce carbon emissions by at least 10%?	N	N	N
1.2a	Will the project be designed in a way that substantially reduces dust and odors on the site?	N	N	Y
1.2b	Will the project be designed in a way that substantially exceeds National Ambient Air Quality Standards?	N	N	N
2.1	Will the project team develop a Climate Impact Assessment and Adaptation Plan?	N	N	N
2.2a	Will a comprehensive review be conducted to identify potential risks that would be created by the project?	N	Y	Y
2.2b	Is there an intent by the owner or team to alter the design to reduce these risks and vulnerabilities?	N	Y	Y
2.3	Will the project be designed to accommodate a changing operating environment throughout the project?	N	Y	Y
2.4a	Will a hazard analysis be conducted covering the likely natural and man-made hazards in the area?	N	Y	Y
2.4b	Will the project be designed so that is it is able to recover quickly from short-term hazard events?	N	Y	Y
2.5	Will the project be designed to reduce heat island effects by reducing the percentage of low SRI surfaces?	N	N	N

*#1-Run-to-failure; #2-Premptive replacement; #3-Balanced approach

4.6. Results

Of the 144 items in the checklist, a typical run-to-failure and emergency repair scenario is expected to address 26 items or 18%. This would not be considered sustainable as most items are not addressed. Not a single Leadership or Climate Risk item would be addressed. Plus only three of 26 Quality of Life items and two of 41 Resource Allocation items would be addressed. The only area where a significant number of items would be addressed is Natural World with 21 of 47 items.

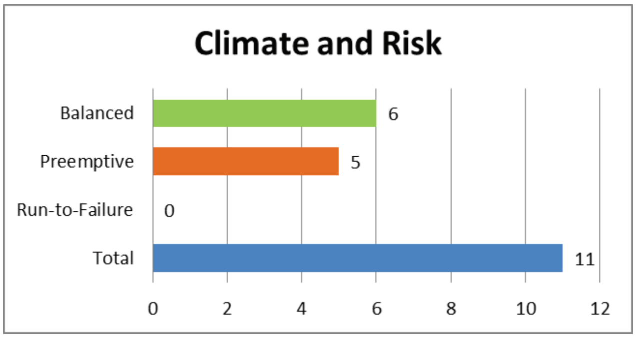

Figure 5. Climate and Risk summary.

Of the 144 items in the checklist, a typical preemptive replacement scenario is expected to address 58 items or 40%. While this is not a majority of the items, it is a substantial increase over the previous scenario. Significant increases in the areas of Quality of Life (ten of 26), Leadership (five of 19), Resource Allocation (12 of 41), and Climate and Risk (five of 11) are seen when compared with the previous scenario. There was also a slight increase in Natural World (26 of 47) items compared with the previous scenario.

Of the 144 items in the checklist, a balanced approach is expected to address 83 items or 58%. This is the only option that meets the majority of the items and it is a substantial increase over the previous two scenarios. Significant increases in the areas of Quality of Life (16 of 26), Leadership (15 of 19), and Resource Allocation (18 of 41) are seen when compared with the previous scenario. There was also a slight increase in Natural World (28 of 47) and Climate and Risk (six of 11) items compared with the previous scenario.

The answers to the questions are based on the experience of the authors, which is a limitation of this paper. It is expected that someone with different experience could interpret the questions and answers slightly differently resulting in varying results. Though this is likely considering the number of questions, the authors do not feel the results would be significantly different from those presented in this paper. It is recommended that the scenarios be completed by additional industry experts and those results be compared to those in this paper for a future paper.

5. Conclusion

The results of the Envision® sustainability evaluation for the three pipe management scenarios showed that the balanced approach to consistently be the most sustainable in all five areas of evaluation. The balanced approach met 58% of the items, which was a significant increase over the preemptive replacement scenario which met 40% of the items. The primary benefits of the balanced approach were mostly related to the less disruptive nature of rehabilitation over replacement and the use of condition assessment to determine when and how to perform repairs. The run-to-failure scenario was consistently the least sustainable, meeting only 18% of the items, mostly due to the lack of planning and design that go into emergency repair actions. The results of the evaluation presented here are beneficial to water utilities and consultants that want to manage water main assets in the most sustainable way possible, which is to use a balanced approach of active condition assessment and non-disruptive repairs when justified.

References

[1] Envision® Pre-Assessment Checklist. Institute for Sustainable Infrastructure (ISI).