Information on Demand: In-house development of a highway preservation database system

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ABSTRACT

The paper discusses the issues within a current highway preservation data integration project. The goal of the project is to integrate all technical and management data into a consolidated properly designed database that enables the organization to deliver evidence based decision-making. The project is an in-house development which is the opposite of many government directions for database development at the moment.

The scope of the database is extensive as it covers all data to support the following data categories related to highway maintenance and rehabilitation:

- expenditures;
- performance;
- inspections;
- inventory management;
- treatment and maintenance budgeting;
- long and short-term condition and performance history; and
- treatments history

All data will be related to the highway inventory and stored for analysis. In addition to the above it is planned that information will be stored in the corporate database regarding the following:

- Shoulders (including the width, type, and condition - linked to tolerability categories as a minimum)
- Risk assessment factors for each segment (updated periodically).
- Defects at a segment level so trends can be tracked over time
- Efficiency and quality of maintenance work

The main focus of the paper is how the design and construction is being managed within the Ministry. Issues surrounding the scope and documentation of the database functionality are covered in detail. How the design is being translated into practice and rolled out with training is also discussed in the paper.

INTRODUCTION

The Saskatchewan Ministry of Highways and Infrastructure highway preservation data system project is by any stretch of the imagination a large government system development. This project involves both enhancing the existing systems and developing much of what is needed from scratch, as much of the functionality of the system does not exist at the moment. The goal of the project is to integrate all technical and management data into a consolidated properly designed database that enables the Ministry to deliver evidence based decision-making for highway preservation.

The preservation data system project began in the fall of 2011. We had recently finished a Preservation Policy Development Project which recommended the development of a number of new performance measures, business processes, technical management tools, data sets and information dashboards for all levels in the organization. We quickly recognized that implementation of the vast majority of recommendations resulting from the Preservation Policy Development Project required the development of a properly integrated database system to house all of the data, information, analysis and management tools.

WHY BUILD IT IN HOUSE?

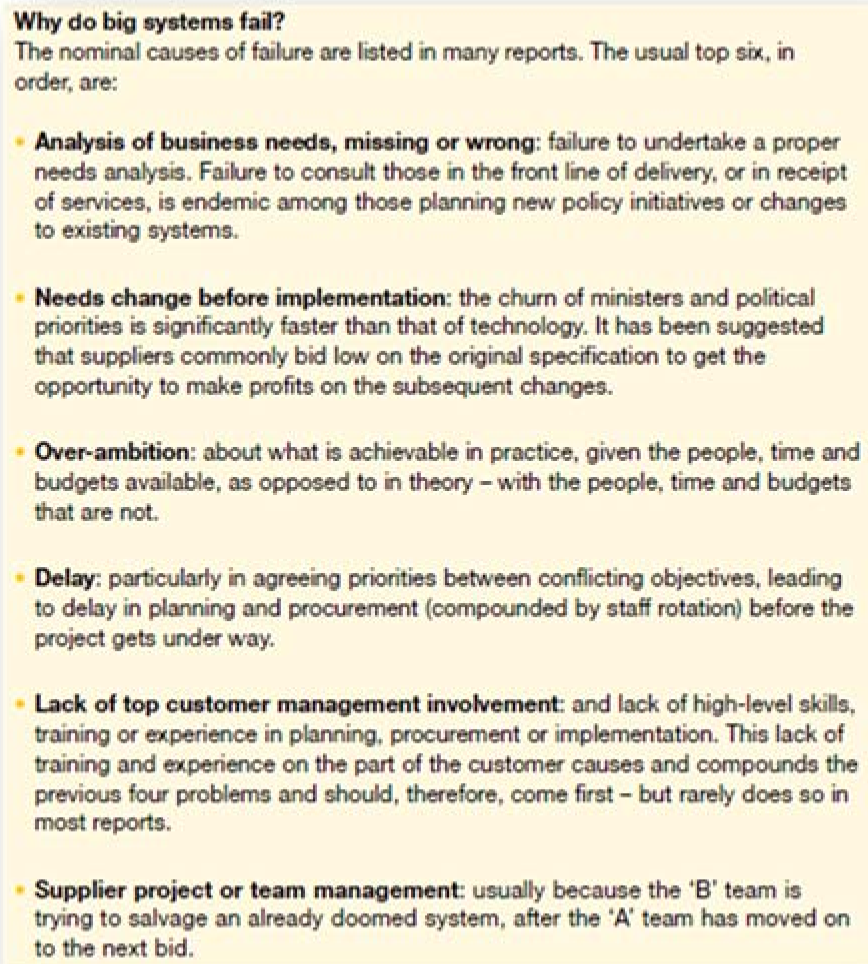
The highway preservation database system is being developed in-house using Ministry staff for the ground up development work, end user testing through to the executive level steering committee and senior management sponsorship. In-house development is the opposite direction for database development of most government organizations at the moment and has many advantages for effectively delivering the project goal.

In his paper titled "Why do we never learn? The pre-conditions for public sector systems success" Philip Virgo (2008) (1), there are many reasons identified why major IT initiatives in the public sector fail. Figure 1 is a direct extract from his paper that lists the top six reasons for failure. The project team for the preservation database project are aware of these challenges and have developed specific techniques to ensure we minimize the risk of these occurring in the project.

The advantages of building the whole system in house are:

a) We are able to consult with Front Line Users to understand needs as the development is evolving, as we are not committed to a rigid specification for the work.
b) We have the inherent flexibility to accommodate Needs and Changes before Implementation as the tools the team are using for building the system allow rapid changes to be made to fine tune each part of the system.
c) We are not over ambitious as the whole system has been split into priority areas which are the only parts that get attention at any stage of the development. Once they are done and accepted then we move forward in the priorities.
d) Defined priority areas means we do not experience delays due to conflicting objectives as the objectives are set early in the process with User Input.
e) The steering committee for the project is made up of executive directors that represent all the users and internal stakeholders of the system. We also have functional directors as sponsors for each part of the system which give us Top Customer involvement and ready access to potential users through the chain of command.

f) Team Management is important to maintain continuity and consistency. The team is made up of employees of the Ministry that have been specifically trained for this project. The external IT input from the IT consultant is to ensure efficiency of coding and to address any particularly complex features that will crop up in various parts of the project (to date there has been no turnover of team members).



Why do big systems fail?
The nominal causes of failure are listed in many reports. The usual top six, in order, are:

- **Analysis of business needs, missing or wrong**: failure to undertake a proper needs analysis. Failure to consult those in the front line of delivery, or in receipt of services, is endemic among those planning new policy initiatives or changes to existing systems.
- **Needs change before implementation**: the churn of ministers and political priorities is significantly faster than that of technology. It has been suggested that suppliers commonly bid low on the original specification to get the opportunity to make profits on the subsequent changes.
- **Over-ambition**: about what is achievable in practice, given the people, time and budgets available, as opposed to in theory – with the people, time and budgets that are not.
- **Delay**: particularly in agreeing priorities between conflicting objectives, leading to delay in planning and procurement (compounded by staff rotation) before the project gets under way.
- **Lack of top customer management involvement**: and lack of high-level skills, training or experience in planning, procurement or implementation. This lack of training and experience on the part of the customer causes and compounds the previous four problems and should, therefore, come first – but rarely does so in most reports.
- **Supplier project or team management**: usually because the 'B' team is trying to salvage an already doomed system, after the 'A' team has moved on to the next bid.

Figure 1. Causes of Failure for Public Sector IT Systems

g) The project manages Political Expectations by adopting realistic timelines and interaction and inclusion of practical experienced people within the team. The high level steering committee assists in expectation management within the Ministry.

h) To manage the scope the whole project has been broken down into self-contained modules. To ensure everything fits together at the end a high level information relationship diagram has been developed so we know which modules feed other modules before any of them are built. Beginning with quick wins (low hanging fruit) has given the project some early successes which are important in maintaining support for the initiative.

i) Start Small, Test Hard, Scale Fast – the immediate goal for any module is to get version one in the hands of the user in an effective way. Transitioning the user from no system to the new system involves user input during the development using on-demand video training packages that can be accessed by the user when needed.

The above approach of building it in house avoids the need to spend excessive time specifying something in detail that does not exist to enable a contractor to bid on it. The experience is that all that effort is often wasted as the real needs are only apparent once the user starts to use the system; therefore the system will evolve and adapt to change over time.

THE PROJECT TEAM

Database Developers: Responsible for all of the database development work. The developers are Regional Data Analysts who are normally responsible for data needs in each of three Regions in the Ministry's Regional Services Division.

IT Consultant: External IT consultant who is available to the database developers on an as needed basis to ensure efficiency of coding and to address any particularly complex features that will crop up in various parts of the project.

Project Manager: Responsible for directing the work of the database developers, setting database standards and protocols and completing database development work. The project is being managed by the Asset Management Specialist from the Ministry's Technical Standards Branch who is normally responsible for data standards.

Project Director: Responsible for keeping the overall project on track; report progress to the senior management steering committee; finding, engaging and reporting to sponsors; setting priorities for development; defining functionality; assisting in scoping development; pitching and receiving approvals for deployment to users.

Sponsors: For many of the database module a sponsor is identified who is the primary most senior stakeholder in the Ministry for the information the database provides. The sponsor helps define the functionality of the particular piece of the database system they are sponsoring, ensures the results meet the business need they were intended to serve and champions the end result.

End Users: Includes users at all levels in the organization from maintenance crew supervisors to senior executive management. End Users are employed in the design and testing phases to ensure the end product meets the end use operational requirements

PLANNING, DESIGN AND CONSTRUCTION

The project is organized into functional planning, prioritization, design, construction and deployment phases. The functional planning phase was completed first and encompasses the entire scope of the project. The functional design phase included mapping relationships between each component of the database functionality. This process revealed how information is connected and dependencies which allowed us to see which pieces need to be developed first and lead into the second phase of the project – prioritization. Development is done in small pieces or modules according the prioritization and we move from detailed scoping to design to construction to end user testing and final deployment one module at a time.

Functional Planning

The initial planning phases for our highway preservation database system began with coming together as a group in a series of brainstorming sessions to scope out information needs. Anything related to highway maintenance and rehabilitation or having an impact on it could be considered as part of the scope. For instance the only data the Ministry had about highway shoulders was the width of the shoulder at the time of construction and maintenance repair records for the cost and hours of work a maintenance crew spent repairing shoulders. There was no information about the type of repair that was being done, how much of the shoulder was repaired, the condition of the shoulder, what triggered the repair work, if the work had been planned, how long the problem existed before it was repaired, or if the repair work fixed the problem. Without shoulder condition information we also had no way of knowing if we were providing an acceptable level of service for highway users, which networks need shoulder repairs, or how much we should be spending on shoulders relative to other investment needs.

The brainstorming sessions identified many current business processes where information was missing or not easily accessible. Often information is stored in someone's spread sheet or a report, multiple versions of the information exists or the information has been lost because of staff turnover. Often the source of the data in a spread sheet or report is not well documented or the data no longer exists in the same format so the analysis is not repeatable. The brainstorming sessions also captured a number of new business processes where the data to support them does not currently exist and would need included the development of the database system.

At the end of the first set of brainstorming sessions we began to group information needs into the following data categories:

- expenditures;
- performance;
- inspections;
- inventory management;
- treatment and maintenance budgeting;
- long and short-term condition and performance history; and
- treatment history

We then began to think about how we want to be able to pull information out of the database system and interact with it. This then lead to the development of the functional requirements for the database and mapping relationships between each function. Figure 2 shows the functional design plan diagram for the database.

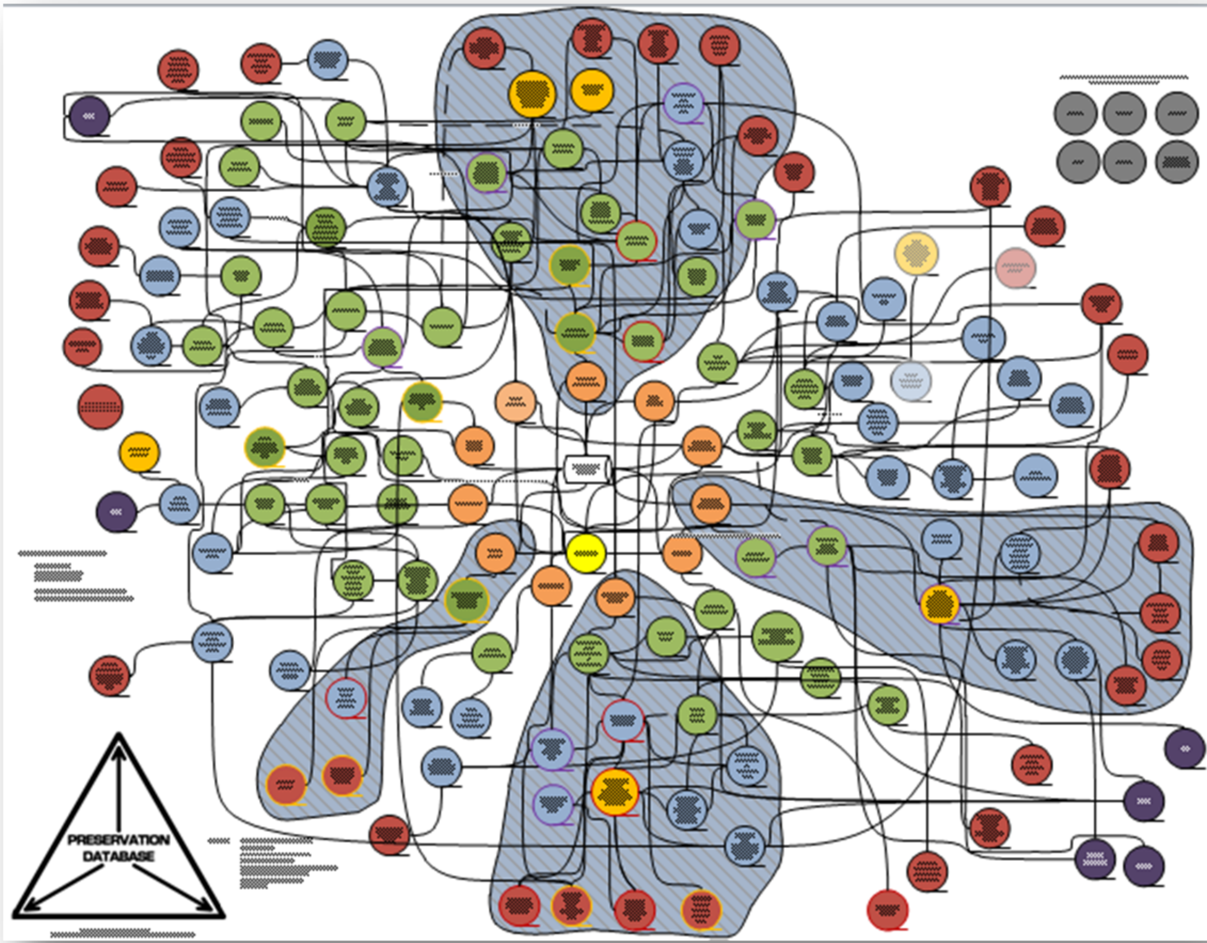


Figure 2. Functional design plan diagram for the database.

Core functionalities of the database are represented by an orange colour circle located in a ring at the centre of the diagram. The core functions or purpose of the preservation database system were established and includes the following:

- Treatment Effectiveness - pavement preservation treatment effectiveness, treatment history, treatment performance and expenditures.
- Asset Integrity - allows us to develop investment plans that target mitigation of risk of failure. Houses defect inspection data, standards for inspection, triggers for preventative maintenance and treatments, performance measure reporting, network risk profiles and trends from year to year.
- Condition Management – houses automated condition data, user input screens for manually collected defect data, process all condition data, managing trigger thresholds for treatments and rehabilitation, reports views and charts of condition data.
- Inventory Management – house base level road asset inventory and tools to manage inventory data. This component will provide inventory trends and statistics.

- Efficiency – maintenance crew performance management, crew productivity, maintenance effectiveness and management of reactive vs. preventative maintenance work.
- Maintenance Strategy - needs based budget calculator that uses defect assessment data to generate amount and type of needed maintenance work, annual work plan development and performance, tools for reviewing work methods and capturing performance improvements, maintenance budget allocation tool, understanding needed vs. deferred vs. planned vs. accomplished maintenance work.
- Consistency – consistency of user driving experience along corridors and management of corridor information.
- Failure History - failure records, type of repairs, response times, failure trends and frequency information.
- Sustainability – financial sustainability, development and comparison of life cycles, life cycle management, expenditures and trends.
- Program Strategy – current, historic and planned programming information including project lists, priorities, strategy comparisons, expenditures and costing.
- Asset Valuation – current and historic financial value of the highway network (s), trends and predictions for or future value under user defined investment in preservation, maintenance and rehabilitation.

As illustrated in Figure 3 the core functionalities are linked to sub functions (green) that are closely related to the core function. Relationships are indicated by arrows between the circles. The diagram also includes key users screens (yellow), tools and calculators (blue) that will interact with users to perform calculation analysis or tasks, business rules and standards (blue) that users will be able to define, and key reports, charts, data views and data maps (red).

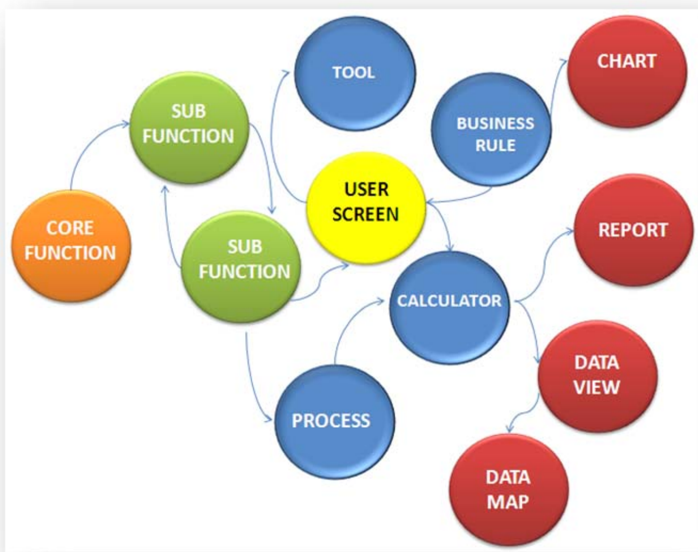


Figure 3. Overview of functional design diagrams

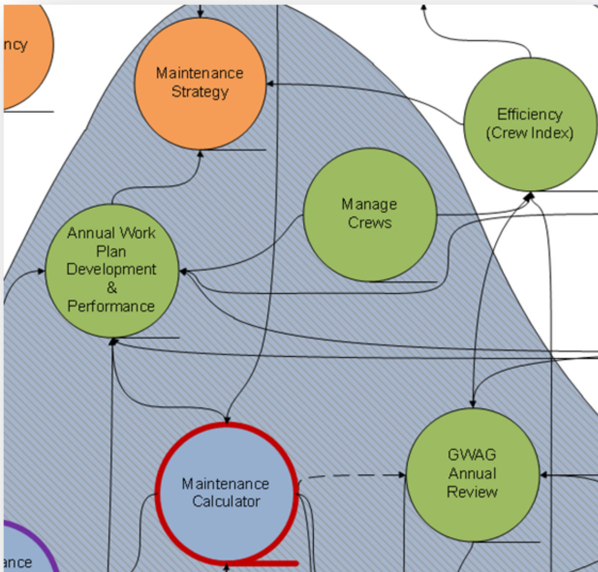


Figure 4. Portion of the Functional Design Plan

Figure 4 is a portion of the functional design plan depicting maintenance strategy. Relationships between the core function (maintenance strategy information), sub-functions (annual work plan development and managing crews) and the maintenance calculator are illustrated with directional arrows connecting each circle.

The functional design plan diagram is a visual representation of the scope for the project. It comes along to all meetings that involve discussion about the project and a current copy is posted in the office of all of the project team members. The diagram is a living document and is regularly updated as progress on the project occurs. We have found that new relationships are uncovered and new circles are added as work on the project progresses.

The functional planning phase also involved documenting a description from the brainstorming sessions about the purpose of each circle in the functional design diagram. Figure 5 is an example of the functional description that is documented for each core function of the database system. It is intended to be a high level description in plain language that anyone can understand. It describes the purpose for the information in the database, relationships, tools and analysis capabilities, as well as the key data views, maps, charts and reports.

A separate document was created for each core functionality of the database and includes the group of closely related circles that appears on the functional design diagram and a description of each one.

MAINTENANCE STRATEGY

DESCRIPTION: Core functionality of the database to house maintenance information and analysis tools to enable development and management of maintenance strategies that align with the overall strategy each network. This component records the maintenance strategy for each road and houses tools to manage execution of the strategy. Tools include analysis to determine annual work plan development, adherence to the plan and exception reporting. Current and historic levels of needed maintenance, planned, actual and deferred maintenance work. Analysis of work methods, costs, crew productivity, and quality of maintenance work to supports adoption of innovation, continuous process improvement and lean management for maintenance work activities. Provides information necessary for strategy development and supports comparison for multiple maintenance strategies.

PARTS & RELATIONSHIPS

Parts	Description and Relationships
Annual Work Plan Development and Performance	Data available for crew work plan development and setting performance measures. Allows comparison of alternative work plans.
Manage Crews	Tools for the management of maintenance crews at the District and Regional levels to ensure delivery of the maintenance strategy set for each Highway network. These tools will provide District and Regional Managers information about options for crew assignments, resource leveling and tradeoffs.
Work Activity Standards Annual Review	Process for review of General Work Activity Guidelines (GWAG). Database should support data required to review and analyze crew specific local work activity guidelines (LWAG) against the standard GWAG.

Key Reports/Views/Charts/Screens

Name	Type	Description
Maintenance Calculator	Calculator, View, Chart, Screen, Report	Tool that takes the defect assessment data and applies logic (standards) to generate needed routine work. Incorporates both Proactive and Reactive work activities and generates starting point (planned), actual and deferred work reports.
Proactive & Reactive Routine Work Triggers/Standards	Business Rules, Standards, Input screen	Should display what the triggers are for generating a volume of work and allow them to be adjusted.
Maintenance Budget Allocation Tool	Tool, Screen, Business Rules	Allows Budget Managers to develop funding options based on needed maintenance work that align with the overall maintenance strategy for each network. Calculates the allocation on funds using the approved funding option. Stores the baseline year start budget allocation, associated work volumes and deferred maintenance amounts.
Edit, enter & maintain Maintenance Calculator Logic Standards	Report, View, Chart, Screen	Logic for the calculation to convert condition and defect assessment information into volumes of need work and type of work. Standard routine activities for particular networks/ surface types/condition states/etc. Need to be able to update and edit the logic. Will be used in the annual work plan reporting. Will be used to report if preventative maintenance was performed according to set standards for networks where a preventative maintenance strategy is adopted.

Figure 5. Database System Functionality Documentation

Prioritization

The functional design diagram in Figure 2 illustrates how overwhelming it would be to try to attempt development of the database without focusing in on one piece at a time. Development is being done in pieces by focusing in on one bubble or a small group of circles (3 or 4) from the database functional plan at a time. The prioritization for development of each piece is largely determined by relationship mapping from the functional design diagram. The connections and dependencies between pieces allow us to see which piece needs to be built first. We quickly discovered that the user input screens for defect assessment data, segment management and treatment history underpin almost the entire database system.

Design and Construction

Design and construction of a module starts with a scoping meeting involving the project team, sponsor, and typically one or two end users. Both the functional diagram and documentation are reviewed. At no point are any technical details discussed. The goal of the meeting is to concisely define the purpose of the circle or group of circles. Why is this module needed? What problem it is solving? What business processes are involved? How will the information be used? How will users interact with the database system? The scope is limited by selecting which relationship lines will be fully developed as part of the scope for the module and how much of each relationship gets into this version of development. If the input screens are required then a mock up of how the screen will look is drawn up on flip charts.

Following the meeting the developers, the project manager and the project director set the scope for the design and construction and set a deadline for completion of the development work. We limit the development to a version one working component that delivers the base functionality as defined. This avoids delays from time spent adding bells and whistles which add no immediate value. The maximum number of pieces in development or deployment is limited to three at any one time. This ensures development work is not fractured and allows the team members the opportunity to collaborate in the design and development, share tasks, and utilize strengths and experience of each member.

A complexity check list to gauge the time constraint that is placed on the development of the module. This check list includes:

- Does it have a user interface?
- Does it require complex algorithms?
- Is data processing needed?
- Does the data exist?
- Does the data exist in the required format?
- Number of business processes involved?
- Number of reports, data views, data maps and reports required?

Upon completion of the checklist the module development is given a complexity rating of Low Medium or High and a time constraint is assigned to the work. Additional questions are added to the complexity checklist as work is completed and we learn from our experience. As the project is progressing our ability to accurately gauge the complexity of development for each module is improving.

When scoping is complete and a time constraint is set for the module we enter into the construction phase.

Often something will occur during the construction phase that affects the ability to reach the goals defined in the scope. When this occurs the developer generates an exception report which we refer to a discovery report as often it involves an enhancement or creative insight that should be incorporated into the database system. The developer documents the idea or enhancement in plain language description for the project manager in the discovery report. The project manager then has a conversation about it with the developer and they discuss the value of the discovery, and time and resource requirement if it was to be incorporated into the version 1 development. The project manager then escalates the opportunity for the incorporating the discovery to the project director and sponsor. The enhancement is not automatically included until permission is received. This instils discipline in the development and avoids bloat of scope. The sponsor and the project director then decide if they want to include the discovery at the version 1 stage or leave it on the to do list for the next version. If the discovery is approved then the scope is redefined and/or the time constraint that was established is adjusted.

Deployment

As the development of a module is completed it must be moved into the hands of the users. This is accomplished through a controlled process of pilot programs, allowing progressively larger groups of users to experience day to day usage of the module. This is particularly useful for modules that are used by field staff, as they are typically more disconnected from the development process. A small pilot group, typically five or so users from different regions of the Ministry is formed, and a training session is held to bring them up to speed as to what the new work process requires of them and how to perform any of the related tasks. This initial training session is also the first opportunity for the development staff to observe the user interaction with any new process or technology. For example, a recent module required field staff to take GPS enabled photos with a camera that was being supplied to them and upload the photos into the database using an application developed for this purpose. At the training session the project team had the opportunity to observe the level of comfort the users had while interacting with the new cameras and using the software. This provided us with valuable feedback on the training materials themselves.

The communication between the development staff and the pilot group users is kept open during the course of the pilot project, ensuring that any feedback is captured in real-time. This is important as it allows the perceived level of any problems to come through. It is easy for a frustrated user to portray a relatively calm (and understated) view of a problem weeks or months after they have experienced it. However, if they are given a chance to report that problem while they are being frustrated by it the level of importance comes through much more clearly. In some cases we are even going as far as providing one-on-one training for pilot program users. This is being done in cases where the component being delivered involves a particularly new or complicated process.

After the initial pilot has been completed a closing meeting is held between the development staff and pilot group users. This meeting is a debriefing of issues experienced, and an opportunity for the users to pass along any issues and suggestions that haven't yet been captured. As well, at this meeting a list of recommendations that will be taken to the program sponsors is finalized and signed off. After this a decision is made whether the program is ready to move into operations, or if another pilot project is required to test the implementation of any improvements. If another pilot is deemed necessary this cycle happens again, typically with an expanded set of users. If enough recommended improvements come from the first pilot project additional development work is done to effectively allow the next pilot to use an upgraded version of the component.

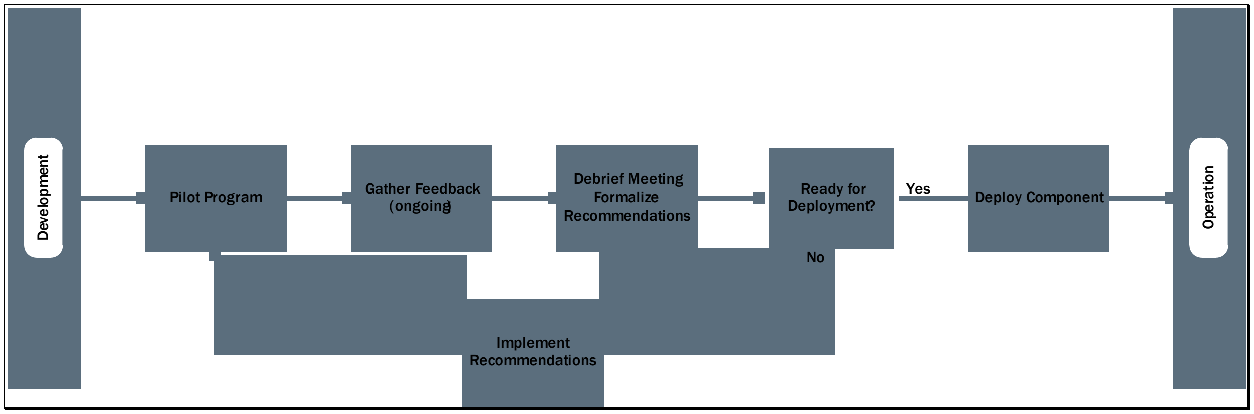
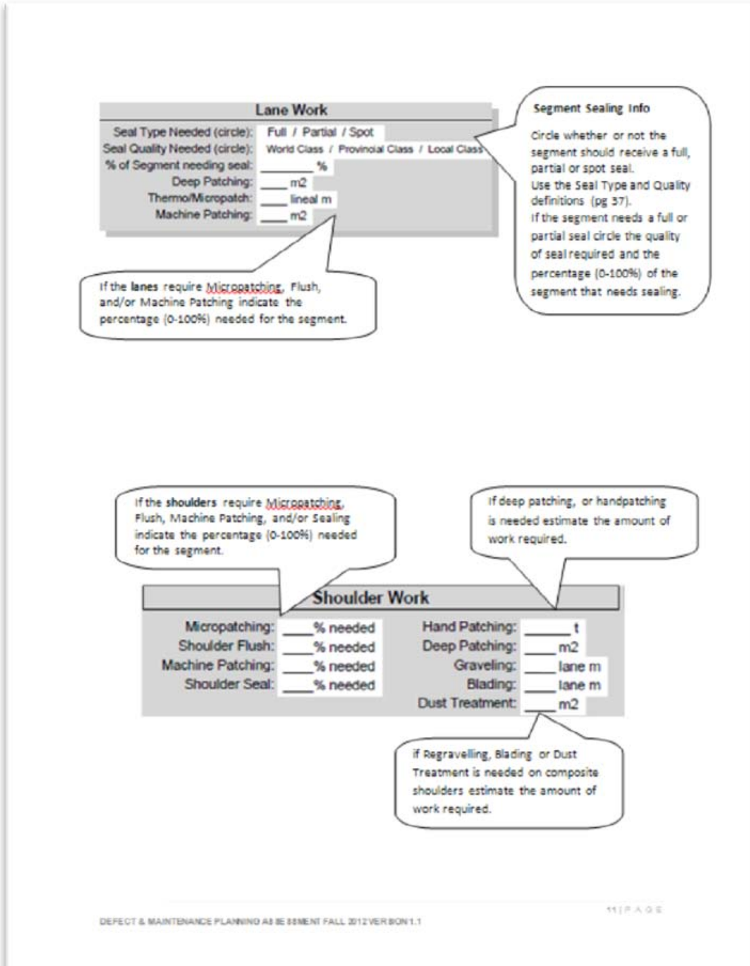


Figure 6. The progressive cycle of pilot programs that take the database component from Development to Operations.

Once the pilot programs are complete and the component is ready to be moved into operations the training is expanded into a full program and delivered province-wide. Workshop style sessions are given, allowing for the same user-developer interaction experienced in the pilot programs. Remote training sessions are also used, typically in cases where travel is more prohibitive. These are accomplished through online meeting systems as webinars.

A range of materials are used to enhance the training. We provide detailed instruction manuals, as well as laminated reference cards for all new procedures.



Lane Work

Seal Type Needed (circle): Full / Partial / Spot
Seal Quality Needed (circle): World Class / Provincial Class / Local Class
% of Segment needing seal: ________ %
Deep Patching: ____ m2
Thermo/Micropatch: ____ lineal m
Machine Patching: ____ m2

Segment Sealing Info

Circle whether or not the segment should receive a full, partial or spot seal.
Use the Seal Type and Quality definitions (pg 37).
If the segment needs a full or partial seal circle the quality of seal required and the percentage (0-100%) of the segment that needs sealing.

If the **lanes** require Micropatching, Flush, and/or Machine Patching indicate the percentage (0-100%) needed for the segment.

If the **shoulders** require Micropatching, Flush, Machine Patching, and/or Sealing indicate the percentage (0-100%) needed for the segment.

If deep patching, or handpatching is needed estimate the amount of work required.

Shoulder Work

Micropatching: ____% needed
Shoulder Flush: ____% needed
Machine Patching: ____% needed
Shoulder Seal: ____% needed
Hand Patching: ______ t
Deep Patching: ____ m2
Graveling: ____ lane m
Blading: ____ lane m
Dust Treatment: ____ m2

if Regravelling, Blading or Dust Treatment is needed on composite shoulders estimate the amount of work required.

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Figure 7. Sample page from a User Guide illustrating how to fill out a data collection form.

These allow the users to keep an easily accessible reference handy to address any simple issues that naturally arise when learning a new process. We are also creating videos that illustrate a typical user performing the tasks associated with a given component. The key benefit of this is that the users are actually able to observe someone physically performing any tasks, rather than just having them described. We use actual personnel from our field staff as the “actors” in the videos, which provides a level of familiarity to the users.

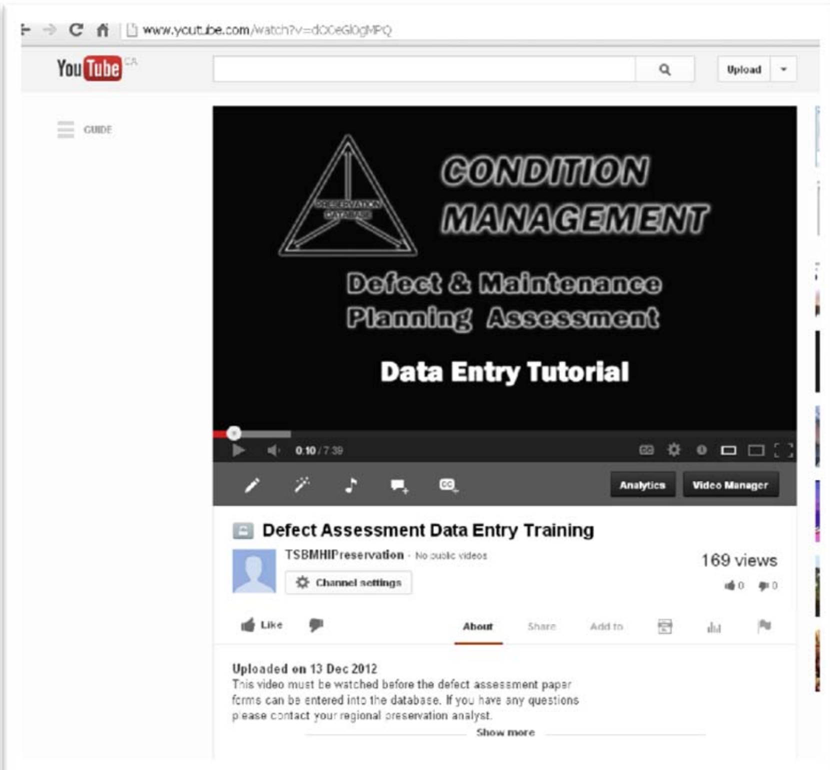

Figure 8. Example of a Training Video, Deployed via YouTube.

Our main focus throughout the process of deploying any component is maintaining a connection with the user base. Pilot programs enable strong feedback, while testing the component in a day-to-day use environment. This supports the overall concept of in-house development very well, as it is consistent with the goal of avoiding disconnecting the users from the development.

References

1) *Philip Virgo "Why do we never learn? The pre-conditions for public sector systems success" (2008)* Transformations Vol 2, No 5 Spring 2008 Published by Capgemini and the National School of Government © Capgemini/National School of Government 2008 http://www.eurim.org.uk/activities/tgdialogues/Why_do_we_never_learn.pdf