# A Risk-Based Asset Management Decision-Support System for the Princess Margaret Bridge Rehabilitation

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# Brief Outline

- Introduction
- Core Principles of Asset Management
- Northridge Earthquake 1994 and other Tragic events and Asset Risk Management
- Transportation Agencies and Asset Risk Management
- Controlling Budgets within the means of change
- Business Alliances such JVs and DBs
- Asset Risk Management Decision Support System (DSS) Development Concept
- *Rehabilitation of Princess Margaret Bridge", Canada*

*"2010-2011" –(DB) – 80,000,000 M $Cad.*

# INTRODUCTION

- The principles and practices of asset management constitute a framework for making decisions about planning, programming, design, construction, maintenance, and operations of roadway, bridges, tunnels, and other transportation facilities

# Core Principles of ASSET MANAGEMENT:

1. *<u>Policy-driven</u>: resource allocation decisions are based on a well-defined and explicitly stated set of policy goals and objectives;*
2. *<u>Performance-Based:</u> policy objectives are translated into system performance measures that are used for strategic management and tied to resource allocation process;*
3. *<u>Reliant on Analysis of Options and Tradeoffs</u>: Decisions on how to allocate resources within and across different types of investments are based on an analysis of how different allocations will impact the achievement of relevant polices objectives;*
4. *<u>Focusing on Yielding Decisions Based on Quality Information</u>:* The merits of different options with respect to an agency's policy goals are evaluated using credible and current data. Where appropriate, decision support tools are used to provide easy access to needed information, to assist with performance tracking and predictions, and to perform specialized analysis.
5. *<u>Reliant on Monitoring to Provide Clear Accountability and Feedback:</u>*

   Performance results are monitored and reported. Feedback on actual performance may influence agency goals and objectives, as well as resource allocation and utilization decisions in future budget cycles.

# Background - Northridge Earthquake 1994 & Asset Risk Management

- Tragic events such as the Northridge Earthquake of 1994 starkly illustrate the importance of this topic.

- When this earthquake struck the Los Angeles area on January 17, 1994, it caused extensive damage to Los Angeles freeways, including the collapse of two bridges on Interstate 10 between downtown Los Angeles and Santa Monica, the collapse of the Interstate 5/Antelope Valley Freeway interchange and a closure of a portion of State Route 118 in the Simi Valley.

- The transportation-related economic impact of the event has been estimated to be over $1.5 billion.

# Other Tragic Events & Asset Risk Management

- *Similarly tragic* consequences arose from the collapse of

1. the Mianus River Bridge on Interstate 95 in Connecticut in 1982,
2. from the damage caused along the Gulf Coast by Hurricane Katrina in 2005
3. and by Hurricane Ike in 2008, and
4. from the 2007 collapse of the Interstate 35W bridge over the Mississippi River in Minneapolis.

# Transportation Agencies & Asset Risk Management

- Transportation agencies that own and operate the IHS (Interstate Highway System) are well aware of the risks they face as they deliver a service— providing a transportation network—to the public.

- Further, individual agencies have performed in an exemplary fashion in responding to such events.

- However, the existing tools and approaches developed for asset management are of limited value for managing risk.

# Asset Management and Risk Management

- While asset management principles are not inconsistent with the concept of risk assessment, it is true that this has not been an area of significant focus in many asset management implementation efforts.

- Further, while significant work has been performed on risk assessment for transportation in recent years, there is little guidance available on how to integrate a risk management approach with an agency’s asset management-related processes.

# Controlling budget within the means of change: Selecting the right sources at right cost

- Allocating budget according to risk reduction to create a balance in project potential & affordability
- Utilising cost-effective budget allocations to monitor your project control activities
- Preparing effective reporting documents as a communication solution in budget explanations to other stakeholders
- Developing backup cost control strategies to prepare for economical highs & lows
- Find alternative sources to fit within your Budget

# Business Alliances & Risk Allocation Issues

- **Design-Build** is a project delivery system used in the Construction Industry. A method to deliver a project design & construction services are contracted by a single entity known as the design-Builder or design build contractor

- **DB** relies on single Point responsibility contract & is used to minimize risks for owner & reduce the delivery schedule by overlapping both the Design & construction phases.

- **Joint Venture (JV):** A business alliance of limited duration formed by two or more unrelated or professional entities sharing in profits & losses. Joint Ventures (JV): a convenient, flexible vehicle - To execute many national & international projects

# DB-Gaining Momentum – Project Scoping

- Design- Build is a gaining momentum in its use by Transportation agencies;
- Comfortable with the Quality Management Process used in design-Bid-Build, many agencies are seeking assurance that the Quality level of the completed project with design-build is not compromised.

- "There are cultural challenges that must be overcome within transportation agencies, the contracting industry and private engineering firms to make design–build (DB) successful. These challenges include fear of change, maintenance of control a different way, and avoidance of personnel preferences. The tenets of teamwork, trust, and ownership are critical for the success of DB projects. The owner is critical in making sure all of this happens. Communication, commitments, information sharing, a sense of urgency, and short turnaround times are all important"

"Steven Dewitt (North Carolina DoT) and Pat Drennon (Parsons Brincherhoff) "Ensuring Quality is Built into the Request for Proposal Process"

**"Design-Build – A Quality Process – TRB Circular Number E-C090 January 2006"**

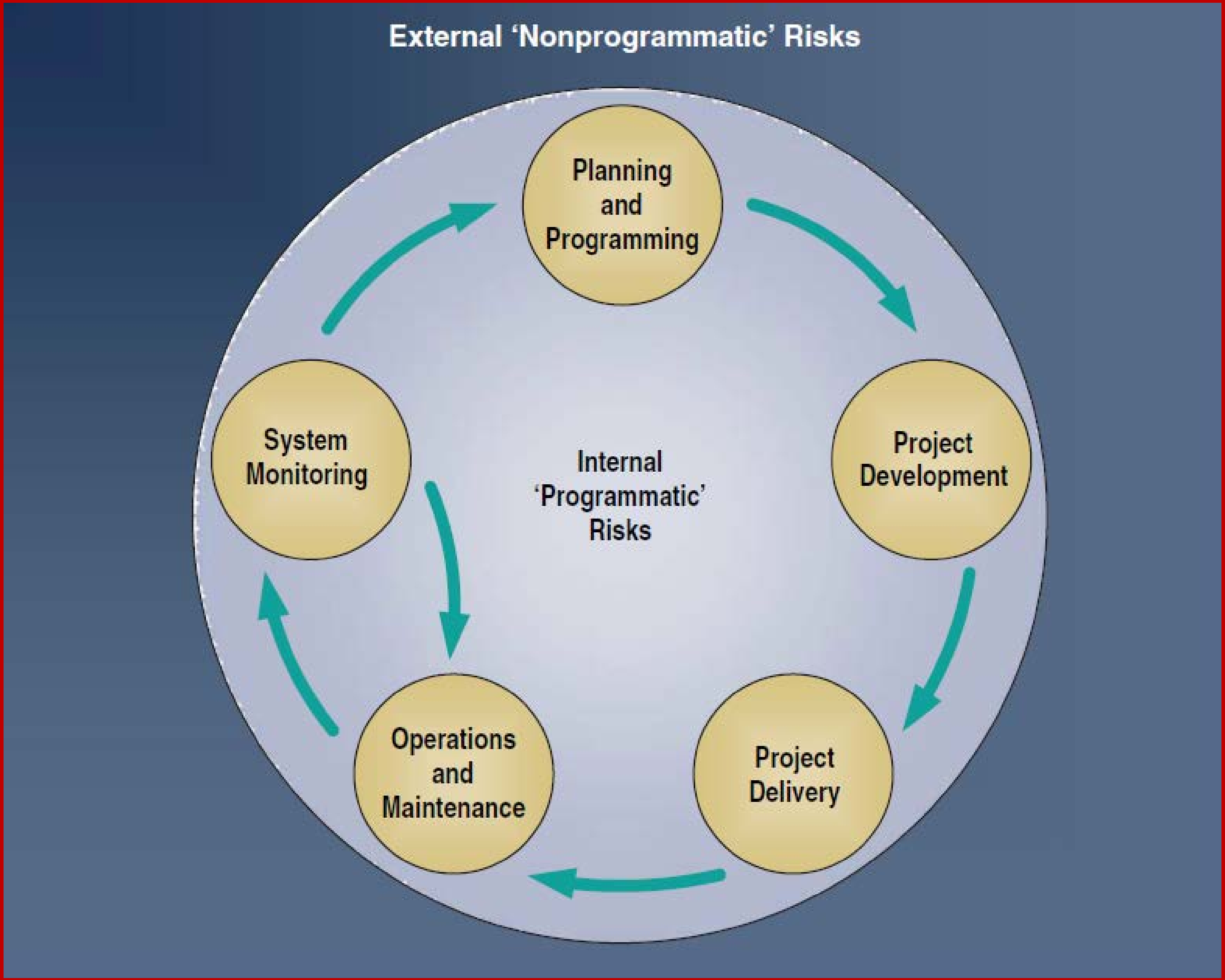
# Risk Categories

- **Known risks :**
  - Minor input variations (labor productivity, swings in material costs)
  - Occur frequently & are an inevitable feature of construction projects.
- **Known/unknown risks :**
  - Events whose occurrence is predictable or foreseeable.
  - The probability of occurrence are normally known.
- **Unknown/unknown risks :**
  - Probabilities of occurrence & effect are not foreseeable by even those most experienced.
  - Usually, considered as “force majeure”.

# Internal Programmatic Risks & External Non Programmatic Risks

**Internal Programmatic Risks.** These are risks that are internalized **in the day-to-day business process of a transportation agency.** Transportation Agencies face a broad range of internal programmatic risks in every part of their operations, from planning and programming, through project development and delivery, and on to maintenance and operations, and finally system monitoring. For example, inaccurate forecasts of asset deterioration and revenues, inaccurate project cost estimates, and unforeseen ground conditions on construction projects fall into this category. Although the frequency of these risks is high and the impact can be substantial, it is rare that they will cause the closure of a link in the transportation system.

**External Non-Programmatic Risks.** These are risks that are addressed outside of a transportation agency's day-to-day business process, either because they are very unlikely, or because they are perceived as external risks over which an agency has little or no control. They tend to relate to the potential for system failure, and may be the result of either the natural environment or human actions. Earthquakes, terrorist attacks, and vehicle/infrastructure collisions that cause the failure of a transportation infrastructure asset fall into this category. Although the frequency of these risks is low, their potential to cause one or more high-priority network links to fail in the event a risk is realized is high.




Existing Transportation Agency Risk Environment –Per NCHRP Report 632, 2009

# Contracting Alliances Risk Areas that Affect the Internal Performance Programmatic Risks for Transportations Agencies

- Construction projects: time, cost & quality targets. (Cooper, 1994;  & Tweeds, 1996) - (Failure to meet targets)
- Risk Management (RM): better understand a project
  - Analyzing different conditions & their probability of occurrence (Smith, N., 1999)
- ICJVs/DBs: challenges & risks
  - Should be identified, classified, & analyzed
  - To evaluate their impact on cost & time.
  - 50 % of JVs  failed, (Beamish, 1993)

# Contracting Alliances Contingency Measures

- Contingency measures:
  High: less likely to win a contract
  Low: could result in significant financial losses (Bohr, 1999)

- A more productive & valuable approach:
  Identifying & classifying the risk factors
  When evaluated & assessed, lead to an overall project risk to compare against an established criterion. (Mulholland & Christian, 1999)

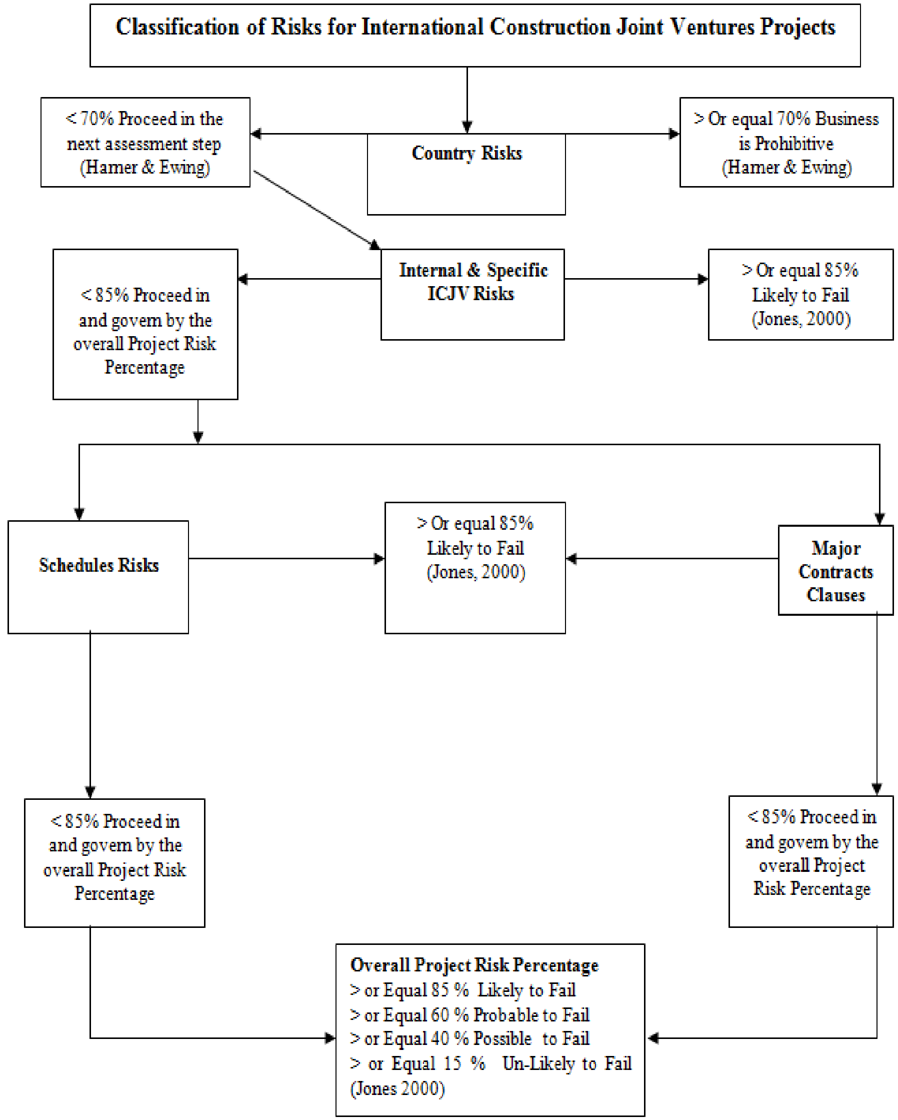
# Asset-Risk Management
# Decision Support System Development

- To establish a simplified ASSET-RISK assessment decision support system for International Construction Projects (JV; DB; P3)
- Compiles the risk factors affecting Business Alliances
- Evaluate & assess the overall project risk
- Compare against established criteria:
  - enable user make better decisions
- Implementation of the DSS on ICJV & DBs for Major Transportation Projects

# DSS Methodology

- Literature review of studies on risk factors associated with the performance of International Construction projects
- Perform classification, grouping, & categorization of risk factors
- Establish evaluation criteria for each category of risk
- Develop an easy to use decision support system pre-determined risk factors
- Validation using different case studies from literature
- Implementation on DB Case

# (Asset Risk Assessment Management System For Construction Operations




Decision Support System Chart

# (Asset Risk Assessment Management System For Construction Operations

- A DSS designed to account for the different risk factors facing the different members involved in the project.
- Includes possible 229 risk factors threatening ICJV/DB Projects, can be narrowed to (126) focal risk factors

| Risk Environments | Risk Number |
|---|---|
| Country risks | (34) |
| Internal, project specific, & external risks | (14) |
| Schedule risks | (61) |
| Major contract clauses risks | (17) |
| Total | 126 |

- Nature of the project
- Where it is located?
- Site visits
- Study the project country
- Competent staff in the project host country
- Fair engineering contract local contractor/subcontractor
- Different price quotations
- Specialists, agents, suppliers
- Brainstorming
- Questionnaires
- Previous experience
- News, media
- Good relation with host government

# DSS Output Evaluation Criteria

- Country risks are the first risk environment to be assessed, the country risks output percentages
- Evaluated according to the (Harner & Ewing, 1985)
  - **Prohibitive country risk (70% - 100%):** Country conditions severely restrict business
  - **High country risk (55% - 69%) :**
  - **Moderate country risk (40% - 54%)**
  - **Low country risk (0%-39%)**

- Other risk environments output percentages & the project overall risk percentage compared to Jones (2000) criteria:

  **Likely to fail> or equal 85 percent**

  **Probable to fail > or equal 60 percent**

  **Possible to fail > or equal 40 percent**

  **0 > Unlikely to fail > or equal 15 percent**

# Overall Project Risk Percentage

- SPR: Severity Probability Rating

**Country risks**
**Internal, Project Specific & External risks**
**Bid Evaluation risks**
**Time Schedule risks**
**Major Contract Clauses risks**
**Contingency risks**

**Overall Project Percentage =**

$$\sqrt{\sum_{1}^{n} (SPR_k)^2 / n}$$

**n = 6, the no of SPR**

# Overall Project Risk Percentage

- SPR: Severity to Probability Factor Matrix
  Sum the environments risks
  Calculate the average
  Assign average risk to the project as a whole

  (High risks contribute more heavily to the overall project & should be weighted more heavily)
- EXAMPLE

| Risk # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Simple Average | Overall Project Risk Formula |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPR | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 2.1 | 2.3 |

(Royer, 2000)

# **Princess Margaret Bridge –** Case Study

Introduction

Opened in 1959 as part of the Route 2 Trans-Canada Highway bypass project around Fredericton. Following a realignment of Route 2 in 2002, the bridge now carries Route 8 the primary Fredericton- Miramichi highway.

# PMB 1958 Original Historic Picture

# PMB 1958 Original Historic Picture

# PMB Configuration

- It is  a 2-lane highway bridge crossing the St. John River & flood plain at Fredericton, New Brunswick, Canada.
- Constructed as a steel truss structure, the bridge measures 1,097 m in overall length.
- A high-level structure supported on tall slender piers in order to provide the required 23 m clearance for the centre navigation span & & to match the topography of the steeply sloping hill side at the bridge’s west abutment.
- The road way is supported by 9 deck truss spans, one through-truss navigation; 7 plate girder spans & 6 rolled beam approach spans;
- The Sub-structure consists of 8 main river piers, 14 land based piers & 2 abutments.

# Bridge Crossing St. John River

# PMB Configuration (Con'd)

- Throughout most of its length, the basic structure of the PMB consists of a concrete deck slab supported on traverse floor beams at 2800 mm centres;
- These floor beams are in turn supported by two main steel carrying trusses or girders which, with the exception of the centre through truss navigation span, are generally spaced at 6400 mm centre to centre.
- The floor beams cantilever 2035 mm beyond the main support trusses on each side of the bridge structure at which point they support the handrail posts & a longitudinal steel truss system which supports the outer edge of the bridge's concrete sidewalk slab.

# PMB Truss Section

# PMB Existing Conditions

- After more than 50 years of operation, the bridge had taken its toll due to:

1. the combined effects of age;
2. Increase in weight & numbers of trucks;
3. The extensive use of de-icing salts to keep the bridge operational during Canada's harsh winter conditions.
4. The deck was deteriorated beyond repairs;
5. The trusses steel members were deficient & with severe corrosion
6. There is also indications of leaking expansion joints;
7. Frozen & non functioning bearing systems;
8. The concrete piers had suffered severe damage;

# Demolition Work

# Existing Conditions (Con'd)

- Signs of deterioration included:

1. Faded paint;
2. Concrete elements spalling;
3. Nettings have been installed to protect pedestrian & motorists below;
4. Deck & floor beams were in bad shape;
5. Expansion joints in poor condition
6. Box seal joints were replaced in Previous rehabilitation but still were leaking

# Structural Assessment

- Rating of the steel member which is the ratio between the remaining of the member capacity after deducting the factored dead loads & the factored live loads has been performed & tabulated.
- Both the capacity & the factored loads were based on the Canadian bridge Code. The used rating equation is as follows.

- $$RF = \frac{\text{Reduced Capacity based on member inspection} - \text{Factored Dead Loads}}{\text{Factored Live Loads} + \text{Impact}}$$

-

# Structural Assessment (Con'd)

- Most of the bottom chord members as well as the diagonals using CL625 TRUCK & the heavier live load requirement had rating less than 1.0.
- This necessitates the strengthening of those members.
- The top chord members were made composite with the new deck.
- This composite action tremendously increases the capacity of the top chord members & consequently increases their member rates significantly.
- All bearings with the exception of the fixed spherical needed to be replaced, especially the rocker bearings that were misaligned.

# Seismic Analysis

- Seismic analysis was performed using 5% return period in 50 years which is an event every 1000 years.
- The bridge is located in Fredericton NE which is seismic zone 2 based on the Canadian bridge code.
- The bridge is classified as an emergency route bridge based on Project specifications.
- Because of the nature of the bridge, Multi Mode Spectral Method was performed & Soil springs values were used.

# Seismic Analysis

- The soil was classified as soil type IV in the Canadian bridge design Code.
- The response spectrum were constructed & applied to the finite element model of the structure.
- Displacements of the roller bearings were obtained then the bearing & the pedestals were designed to prevent the potential unseating.
- The reactions of the fixed bearing were obtained as well to make sure that the bearings have enough strength to sustain these forces.

# Project Structure & Procurement

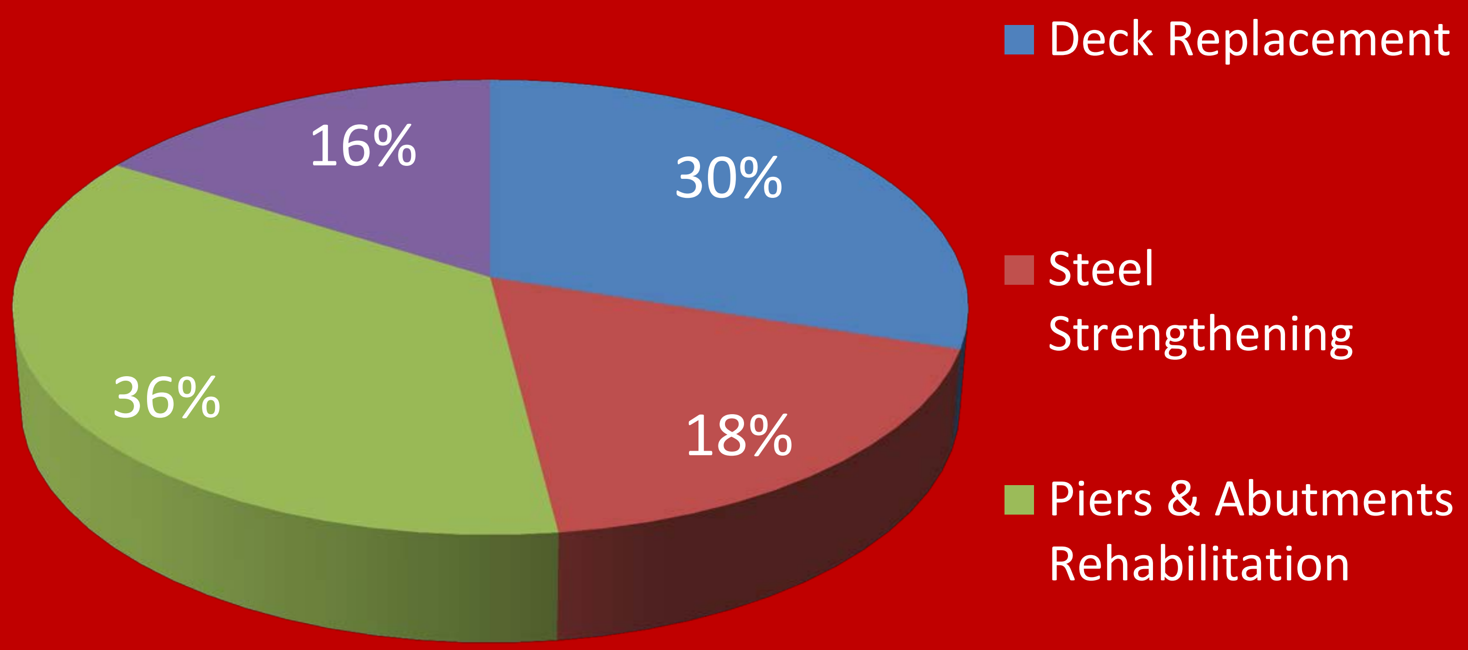
- The project delivery method was as a 2 years DB project using a 2-staged tendering process:
- A. Public Invitation for prequalification in which several consortiums, uniting designers, constructors, project management teams, & pre-casters submitted prequalification's application
- B. Five proponents were eventually invited to submit a detailed technical proposals & a value engineering submission in separate envelopes.

# Project Structure & Procurement

- The major bridge rehabilitation project was developed on the basis of the following scope:

1. Complete Bridge Deck Replacement;
2. Structural Steel Strengthening;
3. Encapsulation of all Concrete Piers & Abutments;
4. Bridge Painting

# Scope of Work



# Challenges & Innovations

- “Precast deck panels are made composite with the trusses” To our knowledge, this is the first time trusses were made composite with a precast concrete deck panels.
- Not only did this solution speed up construction, but also saved a significant amount of structural steel strengthening.
- The deck concept consists of double tee panels in which the panel ribs oriented transverse to traffic.
- The 180 mm double tee slab was post-tensioned in the longitudinal direction to traffic. A very unique innovative system of post-tensioning that eliminated all the duct coupling & possible misalignment was implemented for the first time.

# Challenges & Innovations (Con'd)

- A composite section was created between the deck slab & the steel members. This composite section improved the capacity of those members & reduced strengthening amount.
- Composite sections were created between the deck panels & the following steel bridge members:

1. In the Deck Truss area between the top chord & the deck panels [first time to be implemented to the knowledge of the authors]
2. In the Plate Girder area between the top flange & the deck panels
3. In the Through Truss area between deck panels & the floor beams

# Challenges & Innovations (Con'd)

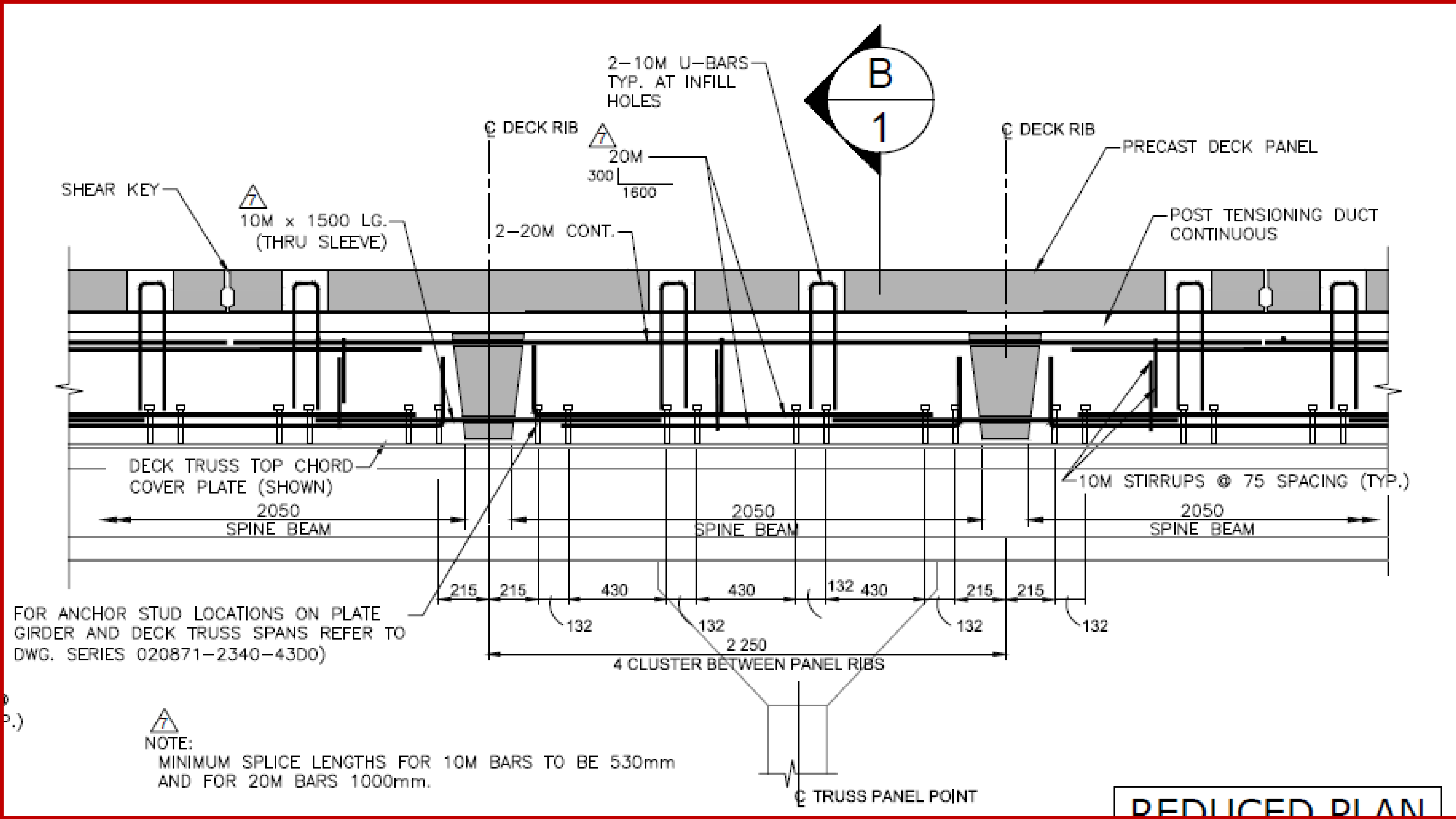
- Deck Truss panel was pre-tensioned transversally & post-tensioned longitudinally, which created a challenge to create the composite action. The composite actions to the steel members are achieved as follows:

1. For both Deck Truss & plate girder, a spine beam was detailed to connect either the plate girder top flange or the deck truss top chord to the deck panels after the post-tensioning operations.

2. For Through Truss the composite action was created through a shear key between the panels in which shear studs are welded to the floor beams.

# Innovations – Composite Action

# Composite Action between the Precast Deck & either the Plate Girder Top Flange or the deck Truss Top Chord



# Constructability Challenge - Deck Removal & Replacement Equipment

# Deck Removal & Replacement in Truss Section Equipment

# New Construction for Bridge Deck Reconstruction: Deck Trusses & Plate Girders

- The deck design at the deck trusses & plate girders area consisted of precast double tee panels with the pre-tensioned ribs oriented transverse the direction of traffic.
- The typical double tee width is 4.5 m & length 9.66 m.
- The ribs were orientated in the transverse directions to comprise the floor beams & to span between the two main girder lines.
- A unique system of post-tensioning the double tee slab parallel to the direction of traffic eliminated all duct coupling & possible beams misalignment has been implemented.

# Installation of a Typical Precast Panel

# Bridge Painting

# Through Truss Deck Panel

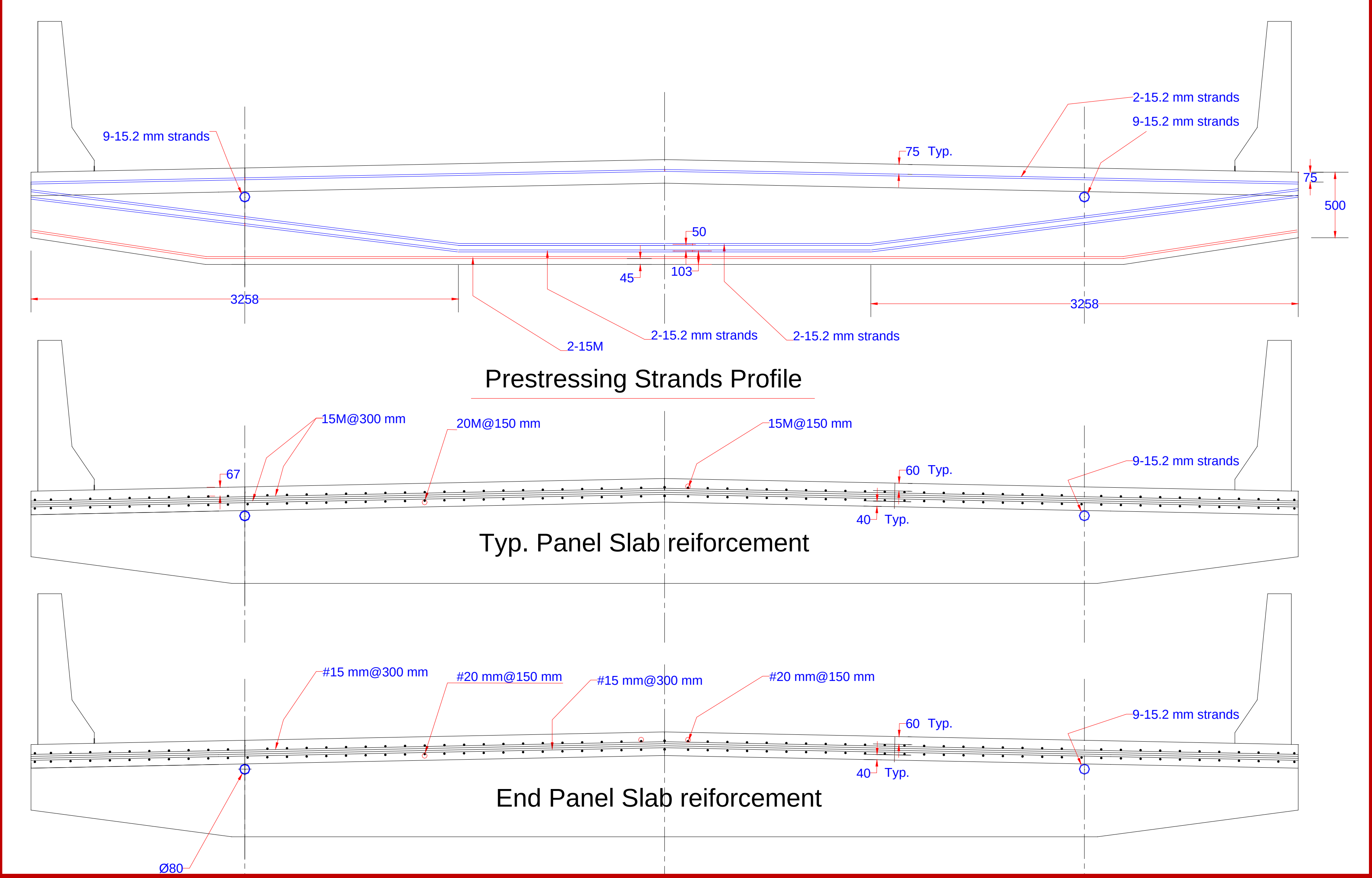
# Deck Panels Fabrications & Construction

- The fabrication of the Deck panels was planned in a very efficient way. All the deck panels are double tees.
- The total numbers of panels fabricated was closed to 200 panels.
- The forms of the deck panels can be divided into two groups.
- The first group is the majority of the panels, 173 panels. Of those 153 panels was intended for the deck truss & the plate girders. The rest are 20 panels were for the through truss.
- All the 173 panels have the same rib spacing 2.25 m, & cross section. The panel foot print is 4.5 x 9.66 m. Only one steel form geometry was used for the 173 panels.

# Precast Panels

# East Approach Deck Panels Installation

# Deck Truss & Plate Girder Panel Details



# Deck Panels Fabrications & Construction

- Through Truss double tee panels were oriented in the longitudinal directions which necessitate reversing the crown direction in the panels.
- The same steel forms were utilized again. However the crown forms was reversed using wood forms in the 180 mm slab. This would allow the pre-caster to pretension those panels.

# Deck Panels Fabrications & Construction

- For the Deck Truss, plate girder & Through Truss panels, the plan was to install the panels using 110 T crane. Only one deck span panels were installed using this Crane.
- Very unique light instrument to install the panels much faster & without the cost of strengthen the top chord necessary to carry the temporary crane loads.
- The East approach panels were installed using a 200 Ton crane from the ground

# Precast Panels – Stocking Area

# Precast Panels Stocking Area

# Piers & Abutment Repair

- Most of the bridge substructure components were showing signs of severe deterioration, which take the form of scaling, map cracking, spalling, & delamination of the concrete surface, & corrosion of the embedded steel reinforcement.
- The deterioration was the result of the combined action of alkali-silica reaction (ASR), cyclic freezing & thawing, & the chloride-induced corrosion of steel.
- The encapsulation method was chosen to repair the piers & abutments. This method entails the installation of reinforced concrete jacket around & over the structure. This encapsulation tasks included the following:
- Remove concrete to a minimum of 250 mm from the original profile of pier, with all reinforcement;
- Install a reinforced concrete jacket around & over the pier to completely encapsulate the exposed surface, & using stainless steel for corrosion-resistant steel.

# Concrete Demolition

# Installation of Stainless Steel

# Encapsulation of all concrete Piers & abutments

# Flying Concrete Mixer

# PMB DSS Asset Risk Management Sample

| ID | Category | Risk Title | Risk Decription | R. Status | Conseq. | Prob. | Manageabiliy | Risk Level | Mitigation | M.Status | Action | Action Status | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Contract | Penalties | | Active | High | V. Low | Medium | V. Low | | Completed | | Completed | |
| | | | | | | | | | | | | Completed | |
| 6 | PM | Client diapprovals | | Active | V. High | High | Low | V. High | | Completed | | Ongoing | |
| | | | | | | | | | | | | | |
| 9 | Design | Geotechnical/ | | Active | High | Medium | Medium | Medium | | Ongoing | | Ongoing | |
| | | Seismicity | | | | | | | | | | | |
| 27 | Finance | Cash Flow | | Active | V. High | Low | Medium | High | | Ongoing | | Completed | |
| | | | | | | | | | | | | Onhold | |
| 42 | DB | Repair vs. | | Watch | V. High | High | Medium | V. High | | Completed | | Completed | |
| | | 50 yrs dilema | | | | | | | | Abandoned | | deleated | |
| | | | | | | | | | | Proposed | | Proposed | |
| | | | | | | | | | | Ongoing | | Ongoing | |
| | | | | | | | | | | Completed | | Completed | |

# Conclusion

- This 2 years design build project has been carried out in 2010-2011,
- All construction works were completed to ensure that the Bridge achieves the required live load carrying capacity & service life objectives.
- The use of precast desk panels that are composite with the trusses proved to be a very efficient desk replacement strategy that saved a significant amount on the strengthening of structural steel.

# Conclusion (Cont.'d)

- The innovative system of post-tensioning the double precast panels parallel to the direction of traffic, using the spine beam concept, eliminated all duct coupling & possible beams misalignment.

- The unique light equipment to install the deck panels was instrumental in achieving the required productivity which allowed the project to be completed within the two-year allotted timeframe.

- Ensure extension of the Bridge service life for another 50 Years.

# Conclusion (Cont.'d)

- DSS compiles 126 risks of critical concerns which are threatening the success of the ICJV/ DB
- Breaks down the risks required for an effective RM process
- DSS Increases the effectiveness of ICJV or a DB project scheduling.
- Decreases the amount of uncertainty for ICJV internal/ DB project specific & external risks factors.
- Gives contractors and Transportation Agencies knowledge about contingency risks in ICJV or DB to cover it
- The critical risk factors must be systematically studied from the perspectives of internal, project - specific & external risk groups, & in combination with ICJV development stages.
- Financial, governments policies, project relationships, economic conditions, & subcontractors are considered the most critical in ICJV/DB.

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# Thank you