Interface Management advancement using Risk Assessments

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in
Construction Engineering and Management

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Abstract

Interfaces on construction projects expose owners to risks that often result in substantial impacts to project cost, schedule, and goals (e.g., management of quality and reputation). Interfaces arise from boundary points where interdependency exists, such as physical elements, phases, contracts, tools, people, and organizations. Interface management is the practice of identifying, monitoring, and controlling interface problems. There is still an open question among owners as to how best to address interface problems, and there is relatively little research available in the literature that explores the implementation of interface management. Therefore, this thesis draws from another field, risk management, in order to better understand interface management. The methodology involves mapping risk assessment data from Light Rail Transit projects onto an existing register of 47 interface problems and 6 summarizing factors. Based on this, severity values from the risk assessments are reflected within the interface problems and factors, allowing for the interface problems and factors to be sorted in terms of importance. The results suggest that the most important interface factor is the "management factor", followed by the "bidding and contracting factor", while the leading interface problems are "inadequate negotiation, communication, and coordination", followed by "unclear contract details and poorly written contract". The objective underlying this thesis is to inform project managers as to where they should focus attention and resources, since mitigating the top interface problems will help to improve overall project performance.

Acknowledgements

I'd like to recognize my dear wife, Lindy, for having patience and providing loving encouragement, all while we raised our newborn son, Jasper. I also owe much gratitude to Dr. Simaan AbouRizk for providing the opportunity and support throughout.

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1. Introduction

1.1. Problem Statement

Interface management is an emerging discipline within the construction industry that has grown in recognition due to the many benefits it brings to projects. The rise and relevance of interface management begins with the acknowledgment of interface-related risks and issues present on nearly every project, particularly as projects continue to increase in scale and complexity, both technically and contractually. Such risks and issues contribute substantially to overall project cost and schedule overruns, as well as to reduced quality and overall fulfillment of project objectives. Interface management helps to mitigate such risks. However, there is a lack of consensus among owners as to how best to implement it, and existing research has not yet sufficiently explored the implementation process (CII 2014, Shokri 2014, Daniels et al. 2014, Weshah 2015). Additionally, most research studies on interface issues share the same or similar approaches.

1.2. Research Objective and Contribution

While interface management is yet an emerging discipline, risk management has been extensively researched and plays a critical role in large projects, including Light Rail Transit (LRT) projects in Canada. Considering the significant impact interface-related issues have on projects, the aim underlying the research presented in this thesis is to inform project managers as to which interface problems warrant attention and resources by leveraging existing risk assessment data from LRT projects. The contributing deliverables are (1) a concise presentation of interface issues and factors that have been sorted by relative importance, and (2) the unique method by which such interface issues and factors were sorted.

1.3. Background on Interface Management

1.3.1. Definition of Interface

In the most general sense, an interface is a boundary point across which interdependency exists (Healy 1997). Numerous types of interfaces exist on any project, and it is perhaps for this reason that there is no single agreed upon definition of interface management. Examples of types of interfaces include those between tools, phases, systems, physical elements or components, people, and organizations, to name a few (Weshah et al., 2013). From a project management and research perspective, it is difficult to isolate one type of interface from the rest, since most are interconnected and therefore have an impact on one another. For example, interfacing construction elements may be managed by differing stakeholders, person-to-person interfaces may have an underlying organizational interface, and organizational interfaces may evolve throughout the various phases of a project. To help conceptualize the interconnected nature of interfaces, researchers often attempt to categorize them. For example, Huang et al. (2008) and Godinot (2003) agreed on a high-level breakdown of boundary types: physical, such as adjacent construction elements; temporal, such as construction phases and sequenced work activities; organizational, such as the individuals and teams that work together; and geographical, such as individual stakeholders that must cooperate without a common goal.

1.3.2. Definition of Interface Management

Bringing together elements of definitions from a number of different studies (Stuckenbruck 1988, CII 2014, Huang et al. 2008, and Shokri et al. 2012), we can broadly define interface management as the ongoing identification, monitoring, and controlling of relationships, communications, and deliverables between two or more interface stakeholders.

Across all types of interfaces, there is also a range of physical and operational interface compatibility, which defines the extent to which information is seamlessly transferred across a boundary or the extent to which the connections may be aligned (Healy, 1997). Ideally, although rarely, there may be what Healy calls a "perfect match", where very few problems occur at the given interface. However, most interfaces are either a partial match, or sometimes even a complete mismatch. In these instances, the quality and alignment of the interface may need to be improved, and, if that is not possible, they must at least be monitored and controlled. This is essentially where interface management plays a role.

1.3.3. Significance of Interface Management

1.3.3.1. Relevance

Interface management is gaining recognition both in academia and in practice (Keerthana & Shanmugapriya 2017, Bible & Bivins 2019). Due to continuous advancements in transportation, operations, and communication technologies, projects often bring together a wide variety of stakeholders distributed worldwide. As a result, projects are becoming more complex and large in scale, particularly with the increased collaboration between multiple disciplines with their respective objectives serving a broader common goal (Chua & Godinot 2006, Collins et al. 2010, Shokri et al. 2012, Bible & Bivins 2019). The Construction Industry Institute (2020) has noted in this regard that the complex challenge of multiple interfaces needing to be managed simultaneously is compounded when projects are fast-tracked. Another problem, pointed out by Chua & Godinot (2006), is that complex projects tend to have autonomous teams working on mutually dependent tasks/projects, and this increases the likelihood of interface errors and other integration problems. The implications of this are increased numbers and types of interfaces that must be managed. The combination of diverse cultures and teams working together across the world creates an environment in which interface management is particularly critical as a means of mitigating interface-related risks (Shokri et al., 2016).

The COVID 19 pandemic has made interface management particularly crucial due to increased shutdowns/restarts, revised schedules, new project practices, and new regulatory requirements. Calas, an Interface Manager at McDermott International, described in a Construction Industry Institute (CII) webinar how pandemics and other major interruptions entail employee turnover, personnel changes, individual relocation, and restructuring of contracting parties (CII, 2020). All of these phenomena, in turn, affect existing connections and relationships between parties and highlight the importance of interface management (CII, 2020).

Stuckenbruk (1983) defended the relevance of studying interface management, pointing out that the success of large, complex, and multidisciplinary undertakings depends on project managers being "very much aware of or even in some cases completely preoccupied with the problem of integrating their projects" (Stuckenbruk, 1983, p. 208). Considering the significant increase in project complexity and changing work environments due to global circumstances such as the recent COVID-19 pandemic, Stuckenbruk's words hold especially true today.

1.3.3.2. Impact of Interface Issues

Interface-related issues are known to increase project cost overruns, time delays, claims, and quality deficiencies on both macro and local levels (Sundgren 1999, Crumrine et al. 2005, Chen et al. 2008, Collins et al. 2010, Shokri 2012, Mhlanga 2018). For example, regarding the mass rapid transit system (MRTS) in Taipei, Huang et al. (2008) found that "several problems resulting from complicated mechanical, electrical, civil, and track interfaces led to enormously extra losses in the construction process" (p. 1). More specifically, Nooteboom (2004) found that interface issues led to an overall 20% cost overrun (in addition to delays and quality problems) for a large, multidisciplinary offshore project.

1.3.3.3. Benefit of Interface Management

Industry leaders employ interface management due its ability to improve alignment between parties and reduce project issues and conflicts (Shokri et al., 2012). In fact, implementing effective and systematic interface management to manage stakeholders and project elements across the entire project life cycle is critical to project performance (Collins 2010, Shokri et al. 2012, CII 2014). Furthermore, Interface Management is claimed by Nooteboom (2004) to be "an effective tool in proactive avoidance or mitigation of any project issues, including design conflicts, installation clashes, new technology application, regulatory challenges, and contract claims, and would enhance the successful delivery of megaprojects" (p. 32). More specifically, early implementation of interface management can help to reduce project cost growth (Nilsen et al. 2018, Sundgren 1999), with the Construction Industry Institute RS302-1 study (2014) finding that implementing formal interface management lowered cost growth by 14%.

Senior Product Manager of Coreworx Interface Management, Maloney, asserted that interface management is effective because it allows communication pathways to be established that can help to prevent or minimize project disruptions (CII, 2020). Moreover, Shokri et al. (2012) pointed out that "through effective IM, project parties not only get a better understanding of the objectives, but also gain better insight into their responsibilities in achieving those goals" (p. 448).

1.4. Analysis of Interface Issues

Understanding the core problems related to interfaces is fundamental to how Interface management must be implemented. For this reason, numerous researchers have endeavored to compile and rank in importance the various issues relating to interface as a way of providing a roadmap whereby project managers might determine where best to focus attention and resources. Various methods have been used to analyze and order interface-related issues. While many researchers and industry leaders have taken an experience-based approach, others have used quantitative analysis. For example, Huang et al. (2008) and Weshah et al. (2013) both used factor analysis to break down larger lists of interface issues into a smaller set of "factors". Both of these studies then determined the order of importance of these interface issues and factors by using multiple regression analysis, with project performance set as a dependent variable, and the various interface problems set as the independent variable.

While the quantitative research to date contributes to construction practice by highlighting the most critical interface issues to be addressed, guidance on how to implement interface management has yet to be sufficiently explored (CII 2014, Shokri 2014, Daniels et al. 2014, Weshah 2015). In addition to there being a need for further research on this topic, the existing research that uses multiple regression analysis has limitations. The correlation between project performance and interface issue criticality in multiple regression analysis is dependent on the quality of responses from interviewees, as well as their subjective perception of what "project performance" really means. For these reasons, the approach that this thesis takes (evaluating interface issues based on existing risk analysis data) contributes to an important field of study in need of further exploration while overcoming some of the limitations of existing research.

1.5. Application of Risk Analysis Data to Interface Issues

Risk assessment and risk management have been the subjects of academic research for roughly 50 years (Aven, 2016), although the earliest record of risk analysis is documented by a group of people called the Ashipu, who lived in the Tigris-Euphrates valley about 3200 B.C (Covello & Mumpower, 1986). This suggests that risk assessment and risk management are, arguably, intrinsic components of human existence, playing an important role in how our society functions as well as how projects are carried out. Researchers have identified a number of benefits of risk management in construction, such as a reduction in project losses, increased profitability, and an increase in the likelihood that project objectives will be fulfilled (Akintoye & MacLeod 1997, Flyvbjerg et al. 2002, Abdelgawad 2011, Zwikael & Ahn, 2011). In this regard, if an organization has the necessary support, established policy and procedures, and technical expertise to implement quality probabilistic risk management (Senesi et al. 2015), the knowledge base of risk assessments and risk management can be leveraged to broaden and deepen understanding of interface issues in order to provide better interface management.

1.5.1. How do the fields of risk assessment and interface management intersect?

Risk assessment and risk management are highly relevant to the study of interface management since interface issues are a subset of risks in construction. Indeed, certain risks may be entirely interface-related, such as the case in which poor communication leads to errors and re-work. Meanwhile, there are other risks that, though they may not be exclusively interface-related, nevertheless are subject to interface dynamics, as in the case of errors in specifications being caused by a miscommunication between two interfaces. In many cases, interface issues are the root cause of the given risk, making the implementation of interface management a reasonable and important risk mitigation strategy. Ultimately, the main objective of implementing interface management is to reduce risk, thereby contributing to the success of the project (Bible & Bivins, 2019).

1.5.2. How can our knowledge of risk assessment benefit interface management?

Given that interface risks are a subset of overall project risks, it is possible to extract risk data that is relevant to interface management. More specifically, our understanding and assessment of risks in a project risk register can be used to extract meaning that will inform interface issues. This thesis is built upon that premise, and as such it makes use of three risk registers, each from a different LRT project. (This is further explained in Chapter 4). Part of the reason LRT projects are well suited to this study is that the risks encountered on such projects are well understood due to their common and recurrent nature (PMI, 2013). Moreover, due to the size and complexity of these projects, interface issues play a significant role, meaning that future LRT projects could benefit from this research.

2. Literature Review

2.1. Interface Management

2.1.1. Definition of Interface

The concept of interface in the context of project management was established following the introduction of the systems approach, which was introduced to the project management field by Wren (1967) and then expanded upon by Morris (1979). Morris defined the systems approach as the combination of people, things, information, or other attributes, collectively seeking a common system objective. Similarly, Wren (1967) defined interface as "the contact point between relatively autonomous organizations which are independent and interacting as they seek to cooperate to achieve some larger system objective" (p. 69). Morris' and Wren's contributions drew attention and awareness to inter-organizational coordination, i.e., the interfaces between parties and how those interfaces are actively managed.

The understanding of interfaces has seen been broadened beyond just inter-organizational interfaces, with more recent studies identifying a wide variety of boundary types. For instance, Huang et al. (2008) and Godinot (2003) both identified, along similar though distinct lines, high-level breakdowns of boundaries as follows: (1) physical, such as adjacent construction elements; (2) temporal, such as construction phases and sequenced work activities; (3) organizational, such as the individuals and teams that work together; and (4) geographical, such as individual stakeholders that must cooperate without a common goal. Although a single definition of interface management does not exist, there is a broad consensus among leading researchers in this domain, including Weshah et al. (2013), Godinot (2003), and Wren (1967), as to the concept of boundary conditions between tools, phases, systems, physical elements or components, people, organization, and others.

Even more generally, Shokri et al. (2012) stated that "Interfaces are generally considered as the links between different construction elements, stakeholders and project scopes" (p. 447). Shokri et al.'s high-level definition of interfaces serves the role of highlighting the ubiquitous nature of interfaces, and it also helps us to understand and visualize specific examples, such as those involved in a mass rapid transit system (MRTS) as described by Huang et al. (2008). Huang et al. suggested that interfaces appear in electrical, civil, functional, physical, organizational, or contractual shapes. Healy (1997), finally, defined an interface as a boundary where interdependency exists, for which responsibility can change. Healy's definition underscores that interfaces are dynamic, evolving, and able to be manipulated and influenced, hence the need for effective interface management.

2.1.2. Definition of Interface Management

With so many different types of interfaces, each with its own unique risks, Stuckenbruck (1988) appropriately described interface management as the continual monitoring and controlling (i.e., managing) of a large number of project interfaces. In terms of what aspects of the interfaces need to be managed, CII (2014) defined interface management as "the appropriate management of communications, relationships, and deliverables among two or more interface stakeholders" (p. I). Along similar lines, Huang et al. (2008) defined interface management as "the matters required to be physically and functionally coordinated or cooperated with among two or more subjects" (p. 53).

The Project Management Institute (PMI) does not mention interface management directly in its *PMBOK Guide* (2013), but it does discuss integration management, which it defines as the process and activity utilized to identify, define, unify, coordinate, and combine the various processes and project management activities within process groups. Mhlanga (2018) argued that the distinction between interface management and integration management is that integration management focuses on the *processes* involved in coordinating multiple project elements, whereas interface management deals primarily with the *identification* of points of contact between stakeholders. In this way, for Mhlanga, interface management is a subset of integration management. Stuckenbruck (1988), meanwhile, argued that interface management includes “continually monitoring and controlling a large number of project interfaces” (p. 230), suggesting emphases on the *process* as well as on *identification*. Stuckenbruck went so far as to assert that “project integration is just another way of saying interface management” (p. 230). To further support that interface management encompasses the active process of managing interfaces, Shokri et al. (2012) stated that “Interface Management, as an effective method in *recognizing* and *communicating* interfaces between project parties and construction components, is an essential tool in successful execution” (p. 448).

For the purpose of the present study, interface management is broadly defined as the ongoing identification, monitoring and controlling of relationships, communications, and deliverables between two or more interface stakeholders.

2.1.3. Categorization of Interfaces

As noted above, Healy (1997) defines an interface is a boundary point across which interdependency exists. Such interdependencies exist throughout projects in many respects. Researchers attempt to categorize interface types for the purpose of better understanding the diverse presence of interfaces on a project. In doing so, project managers gain increased understanding of all aspects of a project that have to do with interfaces. This categorization also helps to facilitate the identification of the various interface-related issues on a project, since many interface issues stem from the inherent nature of the given type of interface. For example, Stuckenbruck (1988) discussed how the three interface types (people, organizational, and system) each pose unique challenges. The combination of personal and organizational interfaces, which Stuckenbruck refers to as management interfaces, is particularly problematic. Stuckenbruck identified the three main interface issues as administrative problems, technical problems, and customer/client problems, all of these being heavily influenced and controlled by managers. The commonly grouped interface types are described in the following subsections, some of the types being more general in nature (e.g. static versus dynamic, and internal versus external), and others being more specific and unique in nature.

Temporal—Static versus Dynamic

Many studies have noted that projects contain interfaces that are shaped by the passage of time or the sequence of phases and events (Healy 1997, Stuckenbruck 1988). Morris (1979) used this concept of time-related interfaces to describe two categories of interfaces: static and dynamic, where static interfaces are the relationships between various functions of a project, such as engineering and procurement, within the same window of time, and dynamic interfaces are the interfaces between sequenced phases of a project. While project managers are often concerned primarily with static interfaces, Caron et al. (1998) suggested that dynamic interfaces—i.e., those between two successive phases—must be adequately managed in order to ensure successful overall project integration.

Internal versus External

Interfaces are often categorized as either "internal" or "external", although the definitions of internal and external tend to vary. Healy (1997) used the term "internal" to mean "within one organization", and "external" to mean different organizations collaborating. In contrast to this, Mhlanga (2018) used the term "internal" to mean "within one project environment", while "external" implies relationships with entities that are not involved in the project in any way. Malanga's interpretation is in line with Collins et al. (2010), who distinguished between internal and external by referring to them as intra-project and inter-project interfaces, respectively. Collins et al. took intra-project interfaces to be the interfaces within a single organization/project, whereas inter-project interfaces are between projects/organizations that, although separate from one another, are still interconnected by an overall common goal. Collins et al. identified a further distinct category, namely, “extra-project” interfaces, which refers to interfaces with parties/organizations that are not directly involved in the project execution and have differing objectives (e.g., permits from government or environmental organizations). Collins et al.’s use of the term “extra-project interfaces” is in line with Healy’s use of the term “external”.

The common link among the categorizations by Morris, Caron et al., Healy, and Collins et al. is that they all focus on the interface *relationship*, rather than the nature of the individual interface entities themselves. The relationships are reflected in the above categorizations, such as those relating to time (static/dynamic), and relative position/role within the project (e.g., project owner being the source of the project, supporting organizations working closely, and consulted organizations outside of the project scope interacting from a distance).

Other Specific Breakdowns

On the other hand, other researchers have organized interface types in more detail to reflect unique attributes in a manner that avoids the distinction between internal/external interfaces. For example, Stuckenbruck (1988) categorized interfaces into “person” interfaces, “organizational” interfaces, and “system” interfaces. “Person” interfaces are the interactions between actual people within an organization, regardless of whether those people are in the same organization or different organizations. “Organizational” interfaces are those between organizations; Stuckenbruck saw these as the most problematic, since organizations often have differing objectives and managerial styles. Finally, “system” interfaces relate to the product, unrelated to the people/organizations working on the product. The “product” can be something physically constructed or physically involved in the construction process, or something operations-/performance-based, whether that be the end-product itself or sub-systems that interface with one another to create an end-product.

Other researchers have categorized interfaces based on their own literature review and unique research objectives. For instance, Chen (2007) advanced the study of “Interface Object Hierarchy”, categorizing interfaces and coming up with the following high-level breakdown:

- Physical: Physical interactions between two or more facility elements or components
- Functional: Functional requirements/influences presented by one functional element/system upon another functional element/system
- Contractual: Interfaces among general contractor, subcontractors, suppliers, and any external providers with regard to their work scopes, schedules, and responsibilities (such interfaces arise from contractual obligations among them)
- Organizational: Interactions between various parties (including divisions in a company) involved in a construction project from its initial conception to its final handover
- Resource: Interfaces between equipment, labor, materials, space, or information necessary to design and construct the facility and its components

Chua & Godinot (2006) researched the use of WBS Matrix to improve interface management on mass rapid transit (MRT) projects, resulting in the following categorization of interfaces:

- Organizational: Internal to the project functions, between project disciplines, and between teams that make up each discipline, and external to the project functions, with external civil/electrical/mechanical contractors.
- Technical: Internally, between sub-systems such as passenger vehicles, signaling systems, platform screen doors, operations control center, power supply, etc., and externally, between electrical, mechanical and civil works.
- Geographical: Interfaces between local and work abroad, or site versus office work
- Time: Between phases of the project (design, construction, etc.), as well as between linear stages of MRT line development.

Miscellaneous categories identified in other studies include contractual interfaces (Miles and Ballard 2002, Pavit and Gibb 2003), as well as compatibility between parties (Healy, 1997). Compatibility refers to the physical and operational transmission of data/resources where the degree of compatibility is assessed to be either a perfect match, partial match, or total mismatch.

2.1.4. Identification and Ranking of Interface Issues

A variety of different approaches to identify, classify, and prioritize the interface-related issues that arise within different project types have been proposed in the literature, although they can be broadly categorized as either qualitative or quantitative. Researchers have endeavored to organize sets of interface-related issues into groups or "factors" within each of these paradigms to help to conceptualize and address interface-related issues.

2.1.4.1. Qualitative Research

Qualitative analysis identifies, reviews, and reports on interface problems based on literature review, pilot studies, and interviews/questionnaires with industry experts, whereas no statistical analysis is conducted (Huang et al., 2008). Interface management issues have been described by many researchers, some building on previous research, while others have come up with their own unique breakdown.

Lisong (2009) researched internal and external stakeholder interactions and identified the following sources of interface conflicts that lead to poor cooperation and erosion of trust:

- Inconsistent interests and targets
- Imbalanced, lagged information and negative communication
- Organization and management factors
- Work cultural conflicts

Song (2016) identified the following interface-related issues that challenge the successful delivery of construction projects:

- High-value engineering/low-cost centers
- Increased technical complexity
- Requirements for local content
- Complex contracting arrangements
- Competing organizational drivers that lead to poor results or outcomes
- Increased scope management complexity
- A less experienced workforce due to resource constraints

The Construction Industry Institute conducted a wide literature review and consulted 16 industry experts in order to identify the following 17 project risk and complexity factors that interface management can help with (CII, 2014):

- Cost pressure (highly competitive bid)
- Schedule pressure (condensed cycle time)
- Scope (extended/unfamiliar, poorly defined scope)
- Execution risk (unknowns)
- Number of joint venture partners (EPCs/owners)
- Technology (new and complex)
- Existence of large number of suppliers/subcontractors
- Multiple engineering centers
- Government rules/regulations
- Multiple general contractors/EPCs
- Large number of engineered items
- Multiple languages
- Unfamiliar partners/collaborators
- Not-aligned software/design standards between parties
- Unclear geographical boundaries within project (“battery limit”)
- Unclear requirements between involved parties

- Unclear responsibilities between involved parties

Godinot (2003 and 2006) explored how to improve interface management on projects, with the findings (by way of inference based on the success factors identified) suggesting that the crucial interface issues to be managed include:

- Poorly defined interfaces
- Poor/limited communication between stakeholders
- Poor/limited visibility on project requirements
- Lack of transparency of work
- Poorly defined responsibilities across interfaces
- Poor control of project activities
- Slow and reactive, rather than proactive and timely management of interface issues

Chan et al. (2004) researched the top critical success factors for enhancing partnership on projects as well as improving overall project performance. Through inference, these success factors can be converted into the following problem factors:

- No implementation of a conflict resolution plan
- Unwillingness to share resources among project participants
- Unclear definitions of responsibilities
- No partnering efforts to combat individual win-lose mindsets

- Short-lived partnering efforts with no ongoing monitoring

Alarcon & Mardones (1998) relied on questionnaires administered to industry experts to determine the leading design–construction interface problems, summarized as follows:

- Limited interaction and coordination between design and construction specialists
- Changes made by owners and designers during construction
- Inconsistencies and defects in design
- Inexperienced designers with little construction knowledge
- Deficiencies within non-technical specifications.

Mhlanga (2018) further identified the following interface issues through a survey administered to industry experts:

- Long lead items
- Permits
- Contract obligations & poor contracting strategy
- Government laws
- Wrong specifications
- Change orders
- Environmental problems
- Poor quality of works

Al-Hammad (2000) identified, based on interviews and a literature review, the following interface problems:

- Financial Problems
    - Delay in progress payment by owner
    - Accuracy of the project cost estimate
    - Owner's low budget for construction relative to requirements
    - Price changes of materials and labourers during construction
- Inadequate Contract and Specification
    - Insufficient working drawing details
    - Insufficient specifications
    - Poorly written contract
    - Change orders
    - Violation of conditions of the contract
- Environmental Problems
    - Weather conditions
    - Geological problems on site
- Other Common Interface Problems
    - Lack of communication between the construction parties

- Slowness of the owner in decision making
- Delay in completion of the project
- Lack of management supervision
- Skills and productivity of labourers
- Poor planning and scheduling
- Poor quality of work
- Unfamiliarity with local laws of related governmental agencies

Crumrine et al. (2005) argued that the root cause of most interface problems can be reduced to three factors:

1. Poor definition of project interfaces, which can lead to scope creep when tying into existing infrastructure
2. Mismanagement of responsibilities, which leads to overlooked details/tasks when responsibilities are shifted between the project management team and those contracted to work on the project
3. Poor social interface management, which leads to differing expectations from the contract if parties are not aligned throughout the duration of the project

In reference to the process of integrating project interfaces, Stuckenbruk (1983) emphasized the role of the project manager in tackling project interface problems, since they provide “a single point of integrative responsibility" and "integrative planning and control". Stuckenbruk went on to describe the following three main categories of interface-related issues:

1. Administrative problems
    - Removing roadblocks
    - Setting priorities
    - Resolving organizational conflicts involving people, resources, or facilities
2. Technical problems
    - Making decisions and scope changes
    - Making key trade-offs among cost, schedule, or performance
    - Deciding on technical alternatives
3. Customer or client problems
    - Interpreting and conforming to specifications and regulatory agency documents

Chen (2007) employed a unique approach in conducting a qualitative review of interface issues, adopting the Cause & Effect (C&E) Diagram (or "fishbone" diagram) proposed by Kaoru Ishikawa in 1968. The C&E diagram is a graphical tool that helps to identify, categorize, and display potential or actual root causes (factors) of a specific effect, problem, or condition. This approach facilitates the formulation of an exhaustive list of items, as opposed to relying on simply gathering input from industry experts and literature review. The objective is to start with some fundamental disparate "perspectives" that will form the main sections of the "fish bone", i.e., the highest level of categorization. These sections are then used to brainstorm more detailed and tangible causes of the ultimate effect (interface problems, in this case). Chen's highest categories consisted of six factors: People/Participants, Methods/Processes, Resources, Documentation, Project Management, and Environment. Figure 1 below shows a sample fishbone diagram of just one factor, Project Management, along with its sub-factors and minor causes.

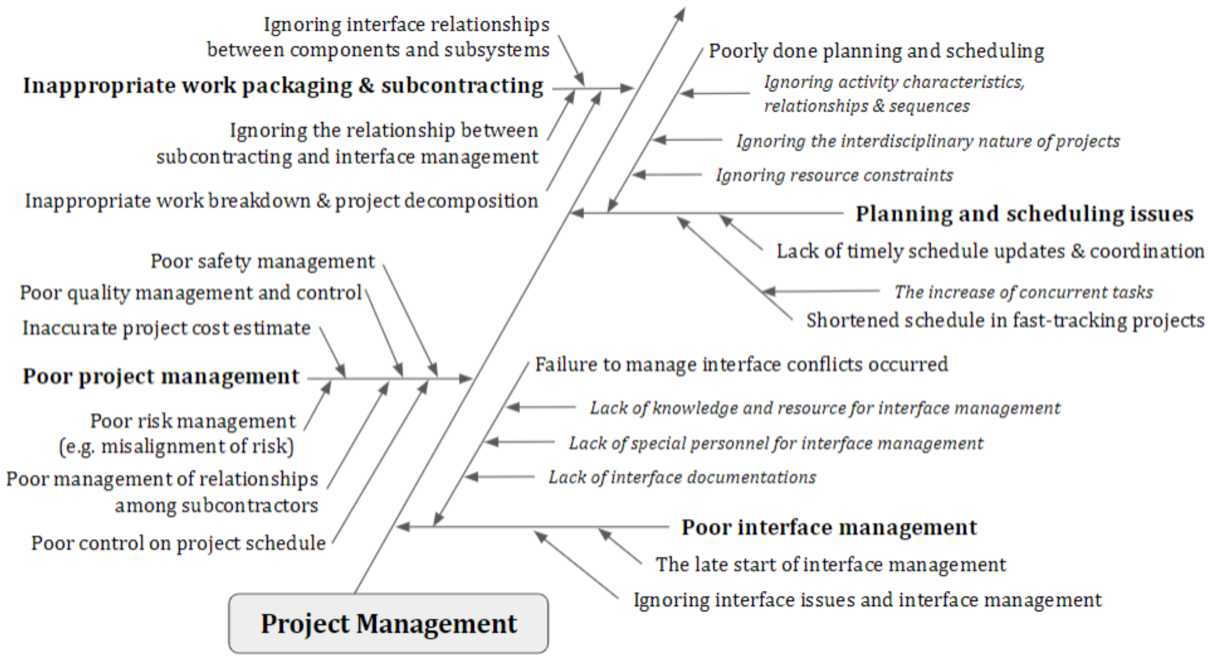

Figure 1: Interface Issue Cause Factors from the Project Management Perspective (adapted from Chen (2007))

In the interest of brevity, the remaining five factors are listed with only their first level of subfactors shown (i.e., excluding lower-branch minor causes):

- People/Participants
  - Poor communication among parties
  - Poor coordination among parties
  - Poor decision making

    - Financial problems
- Methods/processes
    - Construction & assembly problems
    - Manufacturing issues
    - Inferior design in interfaces
- Resources
    - Labour issues
    - Material issues
    - Equipment issues
    - Information issues
    - Space conflicts among labour, equipment, and materials
    - Minor resource issues
- Documentation
    - Lack of interface databases
    - Lack of other interface documentations
    - Delayed permits and shop drawing submission & approval
    - Change order problems
    - Inadequate specifications & drawings
    - Inadequate contract

- Environment
  - Materials and labour availability & price changes in the local market
  - Unsafe working environment
  - Local regulations, building codes & trade union practices
  - Cultural diversity
  - Inclement weather
  - Geological problems at site

2.1.4.2. Quantitative Research

While qualitative research on interface problems is useful for identifying new concepts and consolidating them in an organized fashion, quantitative research significantly increases the value of qualitative information by applying statistical or empirical analysis in order to extract meaning out of data (Weshah, 2015). There are a number of ways to perform quantitative analysis, although factor analysis and multiple regression analysis are by far the most prominent.

Huang et al. (2008) used literature review and face-to-face interviews to compile a list of interface problems, and then used an empirical questionnaire to solicit respondents' attitudes and opinions towards each interface problem using the Likert scale (from 1 to 6) rating system . The first 19 interface problems were sourced from previous research completed by Al-Hammad (2000), mentioned above, while nine additional interface issues relevant to the mass rapid transit system (MRTS) in Taipei were identified based on these interviews:

- Technological improvement
  - Limited personal experience and defective feedback
  - Increase of the uncertainty and ambiguity of interface conflict

  - Emergence of new techniques and new materials
  - Incompetence for solving new technical problems
- Track characteristics
  - Hardship of coordination between interfaces
  - Parties' different opinions on mutual views and needs
- Cultural difference
  - Self-interest perspective
  - Lack of a system updating new information

The quantitative aspect of Huang et al.'s research was the further analysis of the data using factor analysis and multiple regression to categorize the interface problems and measure their degree of impact on project performance. Factor analysis, it should be noted, is a statistical technique used to compress a large set of interrelated variables into a smaller set of "factors" (Kline, 2014). More specifically, Huang et al. used the Kaiser method to extract factors, then identified the ones with eigenvalues (correlation coefficients) greater than 1 and with minimal variance. In this approach, because each factor encompasses an element of each interface problem that is linked to it, the names of each factor are developed based on the common characteristics of the grouped interface problems.

The prioritization of interface problems was completed using multiple regression analysis, with project performance set as a dependent variable, and the various interface problems being the independent variables. Huang et al. (2008) evaluated project performance based on six interface problem factors (independent variables):

1. Experience factor
2. Coordination factor
3. Contract factor
4. Management factor
5. Regulation factor
6. Act-of-god factor

Huang et al. found that the independent variables (i.e., interface problems) had “acceptable” statistical significance. However, of the six interface factors listed above, only two were found to be statistically significant (i.e., p-value < 0.05). Thus, only the experience factor and the coordination factor were found to have a significant influence on project performance, with both having positive standardized coefficients (signifying a positive influence on project performance). From this, Huang et al. concluded that “learning from experience” and “effectively integrating all interfaces” would be decisive causes of a project’s success.

A more recent quantitative study of interface problems was conducted by Weshah et al. (2013). Like Huang et al., Weshah started with a comprehensive review of the literature on interface issues, pilot studies, and face-to-face interviews. From this, 47 interface-related issues, further discussed in Chapter 3, were identified. An empirical questionnaire was then administered to industry experts, who were asked to evaluate the 47 interface issues (on a 6-point Likert scale) in terms of their degree of impact on interface management performance. Weshah then used Pearson's product-moment correlation (PPMC) matrix and factor analysis to identify a smaller set of factors. The PPMC matrix measures the dependence between two or more variables, thus providing the needed confidence that the issues could be grouped into factors. Based on the empirical questionnaire results, the importance of each factor was determined in terms of its impact on project interface management. The six factors are listed below in order of criticality:

1. Management
2. Technical engineering and site issues
3. Information
4. Bidding and contracting
5. Other interface problems
6. By-law and regulation

A unique and recent qualitative study on root causes of interface issues was conducted by Lin & Jeng (2017). They used structural equation modelling, which combines factor analysis and path analysis to investigate the causal relationships among multidimensional factors. This study's main findings were that poor design and ineffective communication and coordination are leading factors for interface problems. They also found that a lack of communication and coordination affects construction work more than owner-related or design elements of a project do.

2.1.5. Areas for Improvement on Existing Research

Aside from the improvements that could be made building on existing research, there is generally a need for further research on the implementation of interface management. Shokri et al. (2012) noted that "although the importance of IM is becoming more widely accepted in today's construction, owners still debate on how to implement IM" (this prompted Shokri et al. to develop a systematic approach for IM). Moreover, Weshah (2015) argued that "for the last two to three decades there has been less than necessary awareness of the essentials of interface management and the severity of interface problems, and this has negatively affected project performance." Daniels et al. (2014), finally, suggested that a notable challenge with respect to the implementation of interface management on mega projects is simply the lack of knowledge as to how it is to be implemented.

Early studies on interface problems have been valuable in that they demonstrate the wide variety of problems relating to interfaces between stakeholders. For example, many studies available in the literature have discussed interface problems between two parties, whether those parties be designers and contractors (Al-Hammad & Assaf 1992), contractors and subcontractors (Al-Hammad 1993, Hinze & Tracey 1994, Mahamid 2017), owners and maintenance contractors (Al-Hammad, 1995), or owners and designers (Al-Hammad & Al-Hammad 1996), while others have considered common interface problems linking multiple (i.e., more than two) construction parties (Al-Hammad, 2000). However, this early research was mostly limited to pilot studies and interviews, providing only a qualitative understanding.

Another problem, pointed out by Chen (2007), is that existing qualitative research on interface-related problems is generally limited to and biased by the individual viewpoints of the authors working on specific problems. Often the scope is too small and only of use within that scope, or the author's own background and unique objective influences the described results. Chen (2007) attempted to resolve this problem by using the Cause & Effect (C&E) diagram, as described in Section 2.1.4.1 above. However, the C&E diagram does not rank the degree of importance of each individual cause. Also, the method of determining the highest-level categorization is based solely on a combination of best practice (standard categories that are often used) and insights into the specific situation at hand. This approach, although methodical, still leaves room for error.

Since then, the research in this area has increasingly made use of quantitative analysis. Although these more recent studies have followed the approach of earlier research when it comes to gathering information—namely, literature reviews, in-depth interviews, and empirical survey questionnaires—they have then further analyzed the responses by means of factor analysis and multiple regression analyses to categorize the interface problems and measure their degree of impact on project performance (Huang et al., 2008). While this represents a significant improvement over a strictly qualitative approach, one of the weak points of this approach is the evaluation criteria. Huang et al. (2008) asked subjects to rate impact on “project performance”, while Weshah et al. (2013) asked subjects to rate “impact on interface management performance”. Such a criterion provide a logical means of judging interface problems, but the limitation is that the quality of the responses can be influenced by resource constraints, time limitations, individual biases, and transparency issues. The assessment of project performance and interface management performance are extremely subjective. Moreover, although having a single criterion by which to assess interface problems is convenient for the survey participants, it lacks specificity. As a result, the accuracy of the highlighted interface problems is dependent on the survey participants' unique perceptions of “project/IM performance”. Ideally, a larger set of criteria would be used that could also be weighted for importance. In this manner, multiple aspects of project performance and interface management performance could be captured in the overall result, providing further accuracy and detailed insights.

Requesting survey participants to evaluate interface factors based on multiple criteria may be too onerous, and as such could lead them to rush the survey, or lower participation altogether. In both cases, the quality of the results will suffer. As an alternative, this thesis addresses the discussed limitation by introducing another set of previously analyzed data, project risks, as further discussed in the chapters below.

2.2. Intersection Between Risk Management and Interface Management

While the use of risk assessments contributes to the overall purpose of this thesis, it is not the primary focus. Nevertheless, it is still important to understand the fundamentals of the risk assessment field. The Project Management Body of Knowledge (PMBOK) defines risk as “an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality" (PMI, 2013, p. 559). The primary component of risk management that is being used in this thesis is the risk analysis component. AbouRizk (2008) identified risk analysis as "the process of identifying risk factors and quantifying those factors to estimate the likelihood and magnitude of their impact".

Both interface risks and interface issues exist on a project, and the only difference between the two is their positioning on the project timeline. Piney (2012) argued that "Risks and issues are different stages in the evolution of a situation, and should be treated in a consistent manner by means of an integrated process." In alignment with this statement, the *PMBOK Guide* stated that "A negative project risk that has occurred is considered an issue" (PMI, 2013, p. 310). In this way, risk management is as relevant to interface issues as it is to interface risks.

The first and most obvious way risk management and interface management relate to each other is that interface management is a subset of risk management in the same way that interface-related risks/issues are a subset of overall project risks (Bible & Bivins, 2019). In other words, interface management is a key component of project risk mitigation. For example, Shokri (2014) aimed to enhance risk management effectiveness in capital projects by developing a strategy to systematically identify and manage stakeholders' interfaces. Shokri found that projects that implemented interface management at a high level experienced lower cost growth and less variation in cost growth. This holds true in particular in the case of highly complex projects, where interface management is crucial for managing the complex network of interfaces (Shokri et al., 2016). For example, Nooteboom (2004) considered the case of a large, multidisciplinary offshore project and found that interface issues led to an overall 20% cost overrun (in addition to delays and quality problems). Moore et al. (1992) asserted that adversarial relationships among stakeholders induce project delays, difficulty in resolving claims, cost overruns, and litigations, and compromise project quality. Further to this, CII (2014) provided a list of 17 risks they determined interface management could help to mitigate. Some of the identified risks were explicitly interface-related (e.g., unclear responsibilities/requirements), while others were more general (e.g., cost pressure due to highly-competitive bids, schedule pressure due to condensed cycle time, poorly defined scope).

Exploring risk management as it relates to interface management (i.e., examining the intersection between the two) constitutes an opportunity to further highlight interface problems using a unique method. Weshah et al. (2014) evaluated 47 interface-related issues through the lens of risk by administering a questionnaire that numerically evaluated the probability and impact of each of the 47 interface issues on a Likert scale (1 to 6). Using the associated ordinal scale for each Likert rating, established by AbouRizk (2008), the severity was then determined by multiplying the average probability of each issue by the impact (i.e., severity = ordinal probability × ordinal impact). Weshah then used AbouRizk's severity groupings to determine the associated risk factor consequence. The outcome of this exercise was a table that grouped each interface issue, defined by probability and impact, into categories (i.e., negligible, acceptable, important, serious, critical, intolerable). Based on the result of the aforementioned risk analysis, the highest-risk IM problems were found to be "planning and scheduling" and "imprecise project cost estimate", both of which Weshah considered to be "management" factors.

In conclusion, the existing research suggest that interface management plays an important role in mitigating interface-related risks, as well as improving overall project performance through cost and time savings and quality assurance (Shokri 2014, Shokri et al. 2016, Nooteboom 2004, Moore et al. 1992). While Weshah et al. (2014) attempted to use a risk assessment process for evaluating interface issues, there is currently no other research that leverages quantitative risk analysis data for the purpose of informing the relative significance of individual interface issues, as being done in the present research.

3. Data Collection

3.1. Interface Problems

Several different research studies have, in an effort to advance the construction industry's understanding of interface issues, set out to identify as comprehensively as possible the interface issues encountered in construction. Over the last two decades in particular, researchers such as Alarcon & Mardones (1998), Al-Hammad (1990, 1993, 1996, 2000), and Mortaheb and Rahimi (2010) have used questionnaires to mine industry expert experience and knowledge to establish extensive lists of interface issues. Researchers such as Huang et al. (2008) and Weshah et al. (2013), meanwhile, have built upon past research by compiling previously identified interface issues, as well as conducting pilot studies and questionnaires to uncover interface issues not previously identified. Weshah's list of interface issues remains the most extensive to date. Mhlanga (2018) studied interface management and conducted surveys with industry experts, although there were not any new types of interface issues identified beyond Weshah's list.

Given that industry interviews and questionnaires have already been completed in other studies, researchers have compiled the findings of previous research, and the literature review conducted as part of the present research did not identify any interface issues over and above those already identified in the literature, the list of 47 interface issues compiled by Weshah et al. (2013) was considered sufficient for the purpose of the present study. The 47 interface issues are listed in Table 1.

Table 1: List of the collected interface management problems based on literature review and pilot study (adapted from Weshah et al. (2013))

No.	Interface Problem	Reference
1	Inadequate negotiation, communication, and coordination among relevant parties involved in the project.	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Graumann & Schlei (1982); R. Huang et al. (2008); Ku et al. (2010)
2	Financial difficulties.	Al-Hammad & Assaf (1992); Al-Hammad (1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
3	Poor decision making.	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
4	Limited skills for labour and engineering.	Al-Hammad (1993, 1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
5	Materials procurement problems.	Al-Hammad (2000); Chen et al. (2008)
6	Construction process problems.	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)
7	Engineering process problems related to interfaces.	Al-Hammad & Assaf (1992); Chen et al. (2008)
8	Project site issues.	Chen et al. (2008)
9	Information problems.	Chen et al. (2008)
10	Lack of project management.	Chen et al. (2008); Mortaheb & Rahimi (2010)
11	Lack of IM system.	Chen et al. (2008)
12	Planning and scheduling problems.	Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
13	Type of organization structure, for example matrix organization increases interface points.	Weshah et al. (2013)
14	Interfaces with other interdependent projects.	Weshah et al. (2013)
15	Undefined reporting structure and responsibilities.	Weshah et al. (2013)
16	Interfaces arise because of the application of the project development gating (or phases) system.	Weshah et al. (2013)
17	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Weshah et al. (2013)
18	Imprecise project cost estimate.	Al-Hammad & Al-Hammad (1996); Al- Hammad (2000); Ayudhya (2011); R. Huang et al. (2008); Ku et al. (2010)
19	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	Ku et al. (2010)

20	Lack of personal experience of the project teams.	Al-Hammad & Al-Hammad (1996); R. Huang et al. (2008); Ku et al. (2010)
21	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Ku et al. (2010)
22	Contractor's unfamiliarity with the environmental circumstances and local weather.	Al-Hammad (1995)
23	Lack of knowledge about site circumstances by the project team members.	Al-Hammad & Assaf (1992)
24	Increase project interfaces conflicts when different contractors insist on their points of view.	Ku et al. (2010)
25	Lack of trust among different project parties.	Weshah et al. (2013)
26	Insufficient and inaccurate work drawings and specifications.	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)
27	No proper work packaging design and subcontracting.	Chen et al. (2008)
28	Slow in change orders, permits and shop drawings submission and approval.	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Ku et al. (2010)
29	Unclear contract details and poorly written contract.	Al-Hammad & Al-Hammad (1996); Al- Hammad (2000); Ayudhya (2011); R. Huang et al. (2008)
30	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	Al-Hammad (1995)
32	Application of fast-track engineering and construction techniques.	Al-Hammad & Assaf (1992)
33	Lack of solid contracting strategy vision at early stage of the project.	Weshah et al. (2013)
34	Type of contracting strategy; EP, EPC, and EPCM.	Weshah et al. (2013)
35	Identification of interface issues in Invitation to Bid.	Weshah et al. (2013)
36	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Weshah et al. (2013)
37	Weather climate conditions problems.	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008)
38	Unexpected changes in materials and labour availability and cost.	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
39	Geological circumstances problems.	Al-Hammad (2000); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
40	Unclear company standard operating procedures.	Weshah (2013)
41	Inexperience with the government auditing protocols and procedures.	R. Huang et al. (2008); Ku et al. (2010)
42	Inexperience with local laws and other government regulations and modification in laws and regulations.	Al-Hammad (2000); R. Huang et al. (2008); Ku et al. (2010)

43	Inexperience with building codes, by-laws, statutes and other government regulations.	Al-Hammad & Assaf (1992); Chen et al. (2008)
44	Project nature issues (brownfield vs greenfield)	Weshah et al. (2013)
45	Free issue items.	Weshah et al. (2013)
46	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Weshah et al. (2013)
47	Unclear system completion requirements.	Weshah et al. (2013)

Weshah et al. (2013) conducted an empirical questionnaire which had 135 participants evaluate the impact of the 47 interface problems on interface management performance. Weshah used a six-point Likert scale with the end points being: 1 = negligible to 6 = disastrous. Participants in the questionnaire included individuals from various industries and company types and representing a range of different job titles and years of experience.

3.2. Interface Problem Factors

In order to interpret the 47 interface problems in a manner that is straightforward for managers to grasp, Weshah consolidated them into a set of factors using Pearson Product-Moment Correlation (PPMC) and factor analysis methods. PPMC, it should be noted, measures the strength of the relationships between variables (in this case, the 47 interface problems). This is critical for determining whether the given data is suitable for being reduced into smaller sets of factors using factor analysis. Factor analysis, meanwhile, is “a statistical technique used to identify a relatively small number of factors that can be used to represent the relationships among sets of many interrelated variables” (Huang et al. 2008). Weshah’s analysis resulted in 6 factors being identified to represent the 47 interface problems. Weshah then confirmed the reliability of the data by testing the factors’ Cronbach’s alpha values, as well as validating the factors using normality and ANOVA tests. The 6 factors Weshah identified are as follow:

1. **Management:** IM issues relating to management, such as limited negotiation, communication, and coordination among relevant parties involved.

2. **Technical engineering and site issues:** IM issues of a technical nature that impact construction work, such as lack of skill/experience, lack of familiarity with site conditions/weather, site congestion or excessive equipment, and construction process complexities.

3. **Information:** IM issues caused by or resulting in information that is overlooked, delayed, inaccurate/insufficient, such as undefined reporting structures and responsibilities.

4. **Bidding and contracting:** IM issues that arise during the invitation to bid and contract execution phase, such as unclear or poorly written contract details, or failure to identify interface issues in the contract.

5. **Other interface problems:** This factor captures two IM problems unrelated to the other factors: "unexpected changes in materials and labour availability and cost", and "project type: brownfield (extension of existing projects) versus greenfield (new) project type".

6. **By-law and regulation:** IM issues arising from project parties lacking experience with government auditing protocols, local laws, building codes, and by-laws, statutes and other governing regulations.

3.3. Project Risk Registers

A project risk register serves as a living document that presents a list of risks within a given project, along with their qualitative and quantitative information. Risk identification and risk analysis must be carried out in order to develop a risk register. Risk identification is the process of listing all of the potential risks on a project using methods such as brainstorming, interviews, workshops, and checklists from similar past projects. Risk analysis, meanwhile, is typically conducted by gathering input from a group of industry experts and stakeholders in a workshop setting. Each individual risk is evaluated for its qualitative information, such as name, description, root cause, etc., followed by its quantitative description, i.e., numeric rating for probability of occurrence and impact. With these quantitative inputs, an overall risk severity is determined based on a risk matrix suited to the given project. The process of risk identification and risk quantification is further detailed in Appendix A. Determining risk severities for each risk allows for the items in the risk register to be ordered in terms of criticality, and for managers to prioritize their attention accordingly. Risk management is carried out on an ongoing basis throughout the life of the project, meaning that risk registers are regularly reviewed by risk managers in consultation with industry experts, allowing for new information and project developments to be reflected in the risk register's quantitative evaluation.

All of the project risk registers used as inputs for the present research are drawn from Light Rail Transit (LRT) projects underway in Canadian cities and at different stages in the project lifecycle, summarized as follows.

- Edmonton—Valley Line Southeast
    - The Valley Line Southeast LRT will run 13 km from Downtown Edmonton to Mill Woods, featuring 11 street-level stops, an elevated guideway, elevated station, a new bridge crossing the North Saskatchewan River, and a short tunnel section, and 26 newly procured Light Rail Vehicles.
- Edmonton—Valley Line West
    - The Valley Line West LRT will span 14 km from Downtown Edmonton to Lewis Farms, featuring 14 street-level stops, an elevated guideway, 2 elevated stations, two new bridges, and 46 newly procured Light Rail Vehicles.

- Ottawa—Confederation Line
  - The Confederation Line spans 12.5 kilometers from Blair Station to Tunney's Pasture, including a 2.5 km tunnel through the downtown core, 13 stations, a Maintenance and Storage Facility, and 34 newly procured Light Rail Vehicles.

Most of the above-mentioned LRT projects are ongoing and, as such, are confidential in nature. For this reason, the information related to LRT risks has been redacted in the following two ways:

1. Specific and unique details that pertain to any particular projects have been altered or omitted so that they cannot be traced back to the originating project.

2. Risk severity quantification is provided for risks, but the source-project is not provided herein.

4. Methodology and Analysis

4.1. Mapping Risks onto Interface Problems

Risk registers are intended to give a comprehensive sense of the risks on a given project. For the purpose of the present work, the objective was to retain the meaning from the risk registers, and effectively overlay their value onto the register of 47 interface issues. The process involved reviewing every risk individually to determine its main characteristics, then scanning through the list of interface issues and assigning the risk to any interface issues that it relates to. As this process relies upon personal judgement, further reflections on the reliability and validity of the methodology are discussed in Section 6.3. Throughout this process, the following observations of the process and outcomes were made:

Many-to-Many relationships - Many risks relate to more than one interface issue, so they were assigned as such. The inverse is also true, where many interface issues are related to more than one risk. For example, the risk, "*Delayed land access on City-identified property*" is related to all of the following interface issues:

- *"Inadequate negotiation, communication, and coordination among relevant parties involved in the project."* This interface issue specifically relates to communication with land owners, city council, land departments, i.e., any entity that owns, regulates, or manages land the project owner must interface with.
- *"Poor decision making."* This applies to relevant decisions such as when to make land available to LRT contractors based on estimated access requirement dates.
- *"Engineering process problems related to interfaces."* This is relevant since proper engineering, including construction work-face planning, will determine how accurate an

estimated access requirement is, and this in turn will influence whether or not land access will be delayed.

- *"Planning and scheduling problems."* The timing as to when access to land is to be obtained must be scheduled according to planned/estimated construction progress.
- *"Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS)."* If the breakdown structures between city and contractor are not aligned, some items may be inadequately monitored, potentially leading to missed deadlines for land access.
- *"Insufficient definition of project battery limits and tie-in."* Battery limits are defined boundaries between two areas of responsibility. If these boundaries are improperly defined and a contractor begins mobilizing on land they are not permitted to be operating on, disputes could arise that further delay the acquisition of the necessary land.

Consolidated Risks - In many instances, a group of risks were consolidated into a single risk by rephrasing them so that they could each be sufficiently represented by that single risk. This occurred with respect to common risks across more than one project, as well as similar risks from within a single project. In both cases, the multiple risks were merged when the differences between the risks were due to a specific difference unique to the project. Distinguishing between risks linked to precise locations/circumstances within a city does not add value to the present study and would also fail to protect project confidentiality.

With regard to the risk of "*Delayed land access on City-identified property"* (mentioned above), Table 2 (Columns D, G, and H) demonstrates how two different projects, A and B, and their respective risks, A1 and B1, are represented by the same risk.

Table 2: Raw data filtered to show interface problems linked to a single risk

	A	B	C	D	G	H
1	**No.**	**Summary of factor analysis**	**Interface problems**	**LRT Risks**	**Project**	**Risk ID**
4	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access	A, B	A1, B1
7	3	Management Factor	Poor decision making.	Delayed land access	A, B	A1, B1
10	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Delayed land access	A, B	A1, B1
13	12	Management Factor	Planning and scheduling problems.	Delayed land access	A, B	A1, B1
16	17	Information Factor	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access	A, B	A1, B1
19	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access	A, B	A1, B1

Another visual representation of the raw data is depicted in Table 3, which illustrates how a single interface problem, "Geological circumstances problems", was found to be linked to three different risks (Column E). It should be noted that some risks can be sourced from a single project (Project A in Row 2 and Project B in Row 4), while others may be from a combination of projects (Project A and B combined in Row 3).

Table 3: Raw data filtered to show risks linked to a single interface problem

	A	B	C	E	H	I
1	**No.**	**Interface Factor**	**Interface problems**	**LRT Risks**	**Project**	**ID**
2	39	Technical and Site Issues Factor	Geological circumstances problems.	Sloped ground collapsing due to natural cause or LRT/third party construction	A	A1
3	39	Technical and Site Issues Factor	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	A, B	A2, B2
4	39	Technical and Site Issues Factor	Geological circumstances problems.	Unexpected geotechnical conditions encountered, increasing construction costs	B	B1

4.2. Ranking Correlations Between Interface Problems and Risks

As discussed in the previous section, there are many risks that apply to multiple interface issues, and most interface issues are related to many risks. However, every link has differing degrees of significance, i.e., the correlation strength between risk and interface issue varies. To capture this difference, a number was assigned to reflect the strength of the correlation. The method used in this research was to use personal judgment to assign a numerical value based on a 5-point Likert scale. Further reflections on the reliability and validity of the methodology are discussed in Section 6.3. Taking the example above of the risk, "*Delayed land access on City-identified property*", the interface issue *"Planning and scheduling problems"* was given a high ranking, 4 out of 5, due to the implicit connection between land access timing and scheduling difficulties, particularly since land access is subject to someone else's control (private business, resident, other project's work site, etc.). For the same risk example, the interface issue *"Insufficient definition of projects battery limits and tie-in"* was given a low ranking, just 2 out of 5, since it is uncommon for battery limits to be defined incorrectly or misinterpreted. The full set of rankings for the above-mentioned risk is shown in Section 4.3, Table 4 (in Column E). The entire log of all interface-risk relationships is presented in Appendix B, which also contains a column with notes adding further clarification on the rankings in cases in which further explanation is warranted.

4.3. Incorporating Risk Severity

Risk severity reflects the overall criticality of a risk, incorporating the probability of occurrence as well as the level of impact. As mentioned in Section 3.3, the risk severities were pre-determined by the municipalities/engineers/consultants in workshop settings prior to the use of this information in this research. As discussed in Section 4.1, links between risks and interface problems were established, meaning the interface problems could also be evaluated in terms of risk severity. The two factors that had to be considered, as mentioned in Section 4.1, were (1) the fact that there were many-to-many relationships between risks and interface issues, and (2) consolidated risks. Having many-to-many relationships implies that a single interface issue will have more than one risk assigned to it, and therefore more than one severity value assigned to it. Additionally, for any risk that is made up of a group of other risks, the severity of the consolidated risk is simply the sum of the respective severities of the constituent risks making up the consolidated risk.

Finally, each severity value was weighted according to the ranked correlation between each risk–interface issue combination. This value, referred to as the "Weighted Severity" (Column L in Table 4), was determined simply as the cross-product between the "Weighting" and "Severity" values—Columns E and J, respectively, in Table 4.

Table 4: Raw data highlighting "Weighting", "Severity", and "Weighted Severity" columns

	C	D	E	G	H	J	L
1	**Interface problems**	**LRT Risks**	**Weighting**	**Project**	**Risk ID**	**Severity**	**Weighted Severity**
4	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access	3	A, B	A1, B1	160	480
7	Poor decision making.	Delayed land access	3	A, B	A1, B1	160	480
10	Engineering process problems related to interfaces.	Delayed land access	3	A, B	A1, B1	160	480
13	Planning and scheduling problems.	Delayed land access	4	A, B	A1, B1	160	640
16	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access	4	A, B	A1, B1	160	640
19	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access	2	A, B	A1, B1	160	320

4.4. Combining Risk Severities from Multiple Projects

The above-mentioned steps constituted the development of the "raw data", illustrated fully in Appendix B. The raw data was of no immediate use until it could be processed in such a manner that each interface issue is represented by a single total severity value that factors in all of the risks across all projects. To obtain the combined severities for the interface problems as well as the interface factors, separate worksheets, referred to as "IM Problem Analysis" and "IM Factor

Analysis", were developed that extract data from the raw data worksheet. The raw data contained interface issues linked to two different types of risks: risks unique to one project, and combined risks that represent a combination of more than one risk/project. The distinct risk link types are tracked in Column G of Table 5 (i.e., "Grouping") for the example of the interface problem "Geological circumstances problems". A blank entry in "Grouping" implies that the risk originates from only one project, while "Combined" means the risk is made up of the adjacent "Separated" risks.

Table 5: Raw data filtered to show "Groupings" of "Combined" and "Separated" risks

	A	C	E	F	G	H	I	K	M
1	No.	Interface problems	LRT Risks	Weighting	Grouping	Project	Risk ID	Severity	Weighted Severity
2	39	Geological circumstances problems.	Sloped ground collapsing due to natural cause or LRT/third party construction	2		A	A1	385	770
3	39	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Combined	A, B	A2, C2	14375	14375
4	39	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	A	A2	13750	13750
5	39	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	B	B2	625	625
6	39	Geological circumstances problems.	Unexpected geotechnical conditions encountered, increasing construction costs	4		B	B1	1250	5000

The highlighted cells in Table 5 illustrate how the values in cells K4 and K5 combined equal the value of cell K3. When attempting to generate the overall severity for a single interface issue/factor in the new worksheets, "IM Problem Analysis" and "IM Factor Analysis", the approach of groupings in the highlighted cells in Table 5 would end up with double-count severities. Therefore, the formula used to extract the severity from the raw data worksheet had to contain a criterion that would only count "*blank*" cells as well as "*Combined*" cells in Column G, "*Grouping",* such that the "Separated" severity values would not be counted*.* The formula is as follows:

```
=SUMIFS(sum_range, criteria_range1, criteria1,[ criteria_range2, criteria2,
... criteria_range_n, criteria_])
```

```
=SUMIFS(range of Weighted Severity,range of ID No. in raw data worksheet, ID
No in Analysis worksheet, range of "Grouping" column, blank) +
SUMIFS(range of Weighted Severity,range of ID No. in raw data worksheet, ID
No in Analysis worksheet, range of "Grouping" column, "Combined")
```

```
=SUMIFS('Raw Data'!N:N,'Raw Data'!B:B,A3,'Raw Data'!H:H,"") + SUMIFS('Raw
Data'!N:N,'Raw Data'!B:B,A3,'Raw Data'!H:H,"combined")
```

In addition to calculating the combined sum, each interface issue was also represented in terms of a severity percentage relative to the other interface issues. These two values were generated for all projects combined, as well as each project individually, so that further analysis could be conducted as the basis for drawing inferences regarding each individual project.

Roughly the same process by which the "IM Problem Analysis" sheet generated the total combined severities for interface problems was followed to generate the "IM Factor Analysis" sheet for interface factors, the one notable difference being the formula checks for matching interface factors (since these are present as their own column for each interface problem).

4.5. Sorting Interface Problems and Factors by Severity

Each interface issue having been assigned a total severity value, the set of interface issues and interface factors could be easily sorted. In so doing, the relative degree of importance of each of the interface issues and interface factors was determined.

5. Results

5.1. Relative Significance of Interface Problems

The sorted interface problems for each LRT project and every unique individual risk and combination of risks contributing to the total combined severity of each interface management problem are presented in Table 6 and further illustrated in Figure 2, where the column, "Total Combined Severity" shows the total of each risk's weighted severity based on all the projects combined. The Total Combined Severity, considered in isolation, is relatively meaningless, other than in demonstrating the relative significance of each interface problem. To help highlight the relative significance of each interface problem, the last column, "Severity Proportion", shows the ratio between each interface problem's total combined severity and all interface problems' severities combined.

Table 6: Relative significance of interface problems

ID	Interface Problem	Total Combined Severity	Severity Proportion (%)
1	Inadequate negotiation, communication, and coordination among relevant parties involved in the project.	555,199	20.2
29	Unclear contract details and poorly written contract.	330,015	12.0
14	Interfaces with other interdependent projects.	213,330	7.8
44	Project nature issues (brownfield vs greenfield)	192,381	7.0
7	Engineering process problems related to interfaces.	168,277	6.1
10	Lack of project management.	162,665	5.9
11	Lack of IM system.	161,020	5.9
12	Planning and scheduling problems.	87,665	3.2
35	Identification of interface issues in Invitation to Bid.	74,325	2.7
34	Type of contracting strategy; EP, EPC, and EPCM.	67,280	2.4

26	Insufficient and inaccurate work drawings and specifications.	61,240	2.2
19	Discrepancies between the owners' expectations regarding project construction schedule, cost, and quality.	57,670	2.1
28	Slow in change orders, permits and shop drawings submission and approval.	55,400	2.0
24	Increase project interfaces conflicts when different contractors insist on their points of view.	49,725	1.8
20	Lack of personal experience of the project teams.	48,120	1.8
15	Undefined reporting structure and responsibilities.	47,315	1.7
23	Lack of knowledge about site circumstances by the project team members.	42,502	1.5
6	Construction process problems.	38,810	1.4
32	Application of fast-track engineering and construction techniques.	38,600	1.4
36	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	38,410	1.4
25	Lack of trust among different project parties.	31,320	1.1
8	Project site issues.	30,887	1.1
3	Poor decision making.	26,585	1.0
30	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	23,800	0.9
43	Inexperience with building codes, by-laws, statutes and other government regulations.	21,575	0.8
39	Geological circumstances problems.	20,895	0.8
21	Incapability to predict and resolve project's problems related to new technological techniques and materials.	14,410	0.5
22	Contractor's unfamiliarity with the environmental circumstances and local weather.	13,610	0.5
9	Information problems.	10,850	0.4
2	Financial difficulties.	10,285	0.4
16	Interfaces arise because of the application of the project development gating (or phases) system.	10,230	0.4
47	Unclear system completion requirements.	8,250	0.3
18	Imprecise project cost estimate.	8,170	0.3
5	Materials procurement problems.	6,250	0.2
38	Unexpected changes in materials and labour availability and cost.	6,250	0.2
46	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	5,890	0.2

17	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	3,140	0.1
40	Unclear company standard operating procedures.	1,625	0.1
41	Inexperience with the government auditing protocols and procedures.	1,625	0.1
42	Inexperience with local laws and other government regulations and modification in laws and regulations.	1,625	0.1
37	Weather climate conditions problems.	1,395	0.1
13	Type of organization structure, for example matrix organization increases interface points.	250	0.0
4	Limited skills for labour and engineering.	0	0.0
27	No proper work packaging design and subcontracting.	0	0.0
33	Lack of solid contracting strategy vision at early stage of the project.	0	0.0
45	Free issue items.	0	0.0

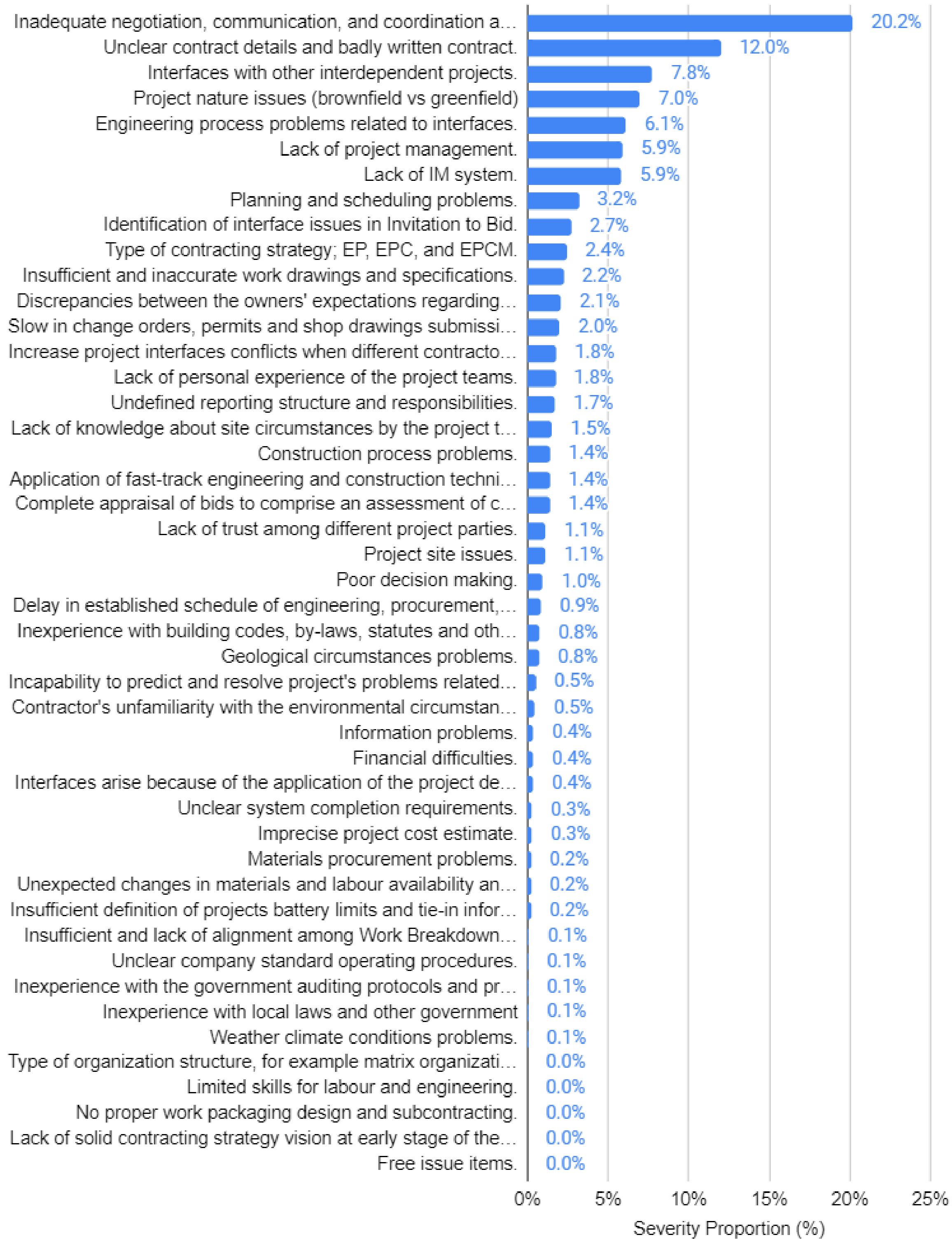

Figure 2: Relative significance of interface problems

Of the 47 interface problems illustrated in Figure 2, it is noteworthy that the top interface problem, "inadequate negotiation, communication, and coordination", is by far the most significant interface problem, followed by "unclear contract details and poorly written contract".

5.2. Relative Significance of Interface Factors

The sorted interface factors for each LRT project and every unique individual risk and combination of risks contributing to the total combined severity of each interface factor are presented in Table 7 and Figure 3. The column, "Total Combined Severity" represents the total of every risk's weighted severity from every project combined. The Total Combined Severity, considered in isolation, is relatively meaningless, other than in demonstrating the relative significance of each interface problem. To help highlight the relative significance of each interface problem, the last column, "Severity Proportion", shows the ratio between each interface factor's total combined severity and all interface factors' severities combined.

Table 7: Relative significance of interface factors

Interface Factors	**Total Combined Severity**	**Severity Proportion (%)**
Management Factor	1,333,219	47%
Bidding and Contracting Factor	657,170	23%
Technical and Site Issues Factor	383,866	14%
Information Factor	232,805	8%
Other Interface Problems Factor	198,631	7%
Law and Regulation Factor	26,450	1%

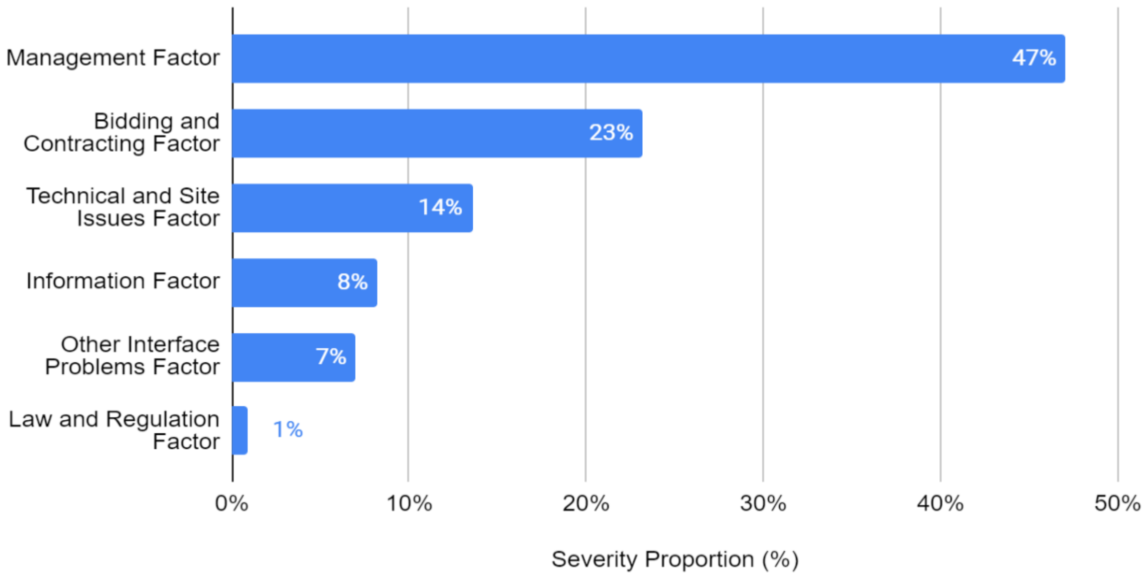

Figure 3: Relative significance of interface factors

From Table 7 and Figure 3, it is worth emphasizing the significance of the Management Factor, which accounts for almost half (47%) of the overall severity values. These results are further discussed in Section 6.2.

5.3. Unique Differences Between LRT Projects

As discussed in Section 4.4, for every risk studied, the project it belonged to was documented. In so doing, interface problem and factor comparisons could be drawn between projects. Due to the confidentiality of these projects, details and inferences are not explicitly discussed herein. Nevertheless, Figure 4 helps to visualize the project comparison, validating the developed methodology in terms of where the projects align in the analysis, as well as providing insights into differences that could be due a number of factors, such as project phase, budget, environment, and scope.

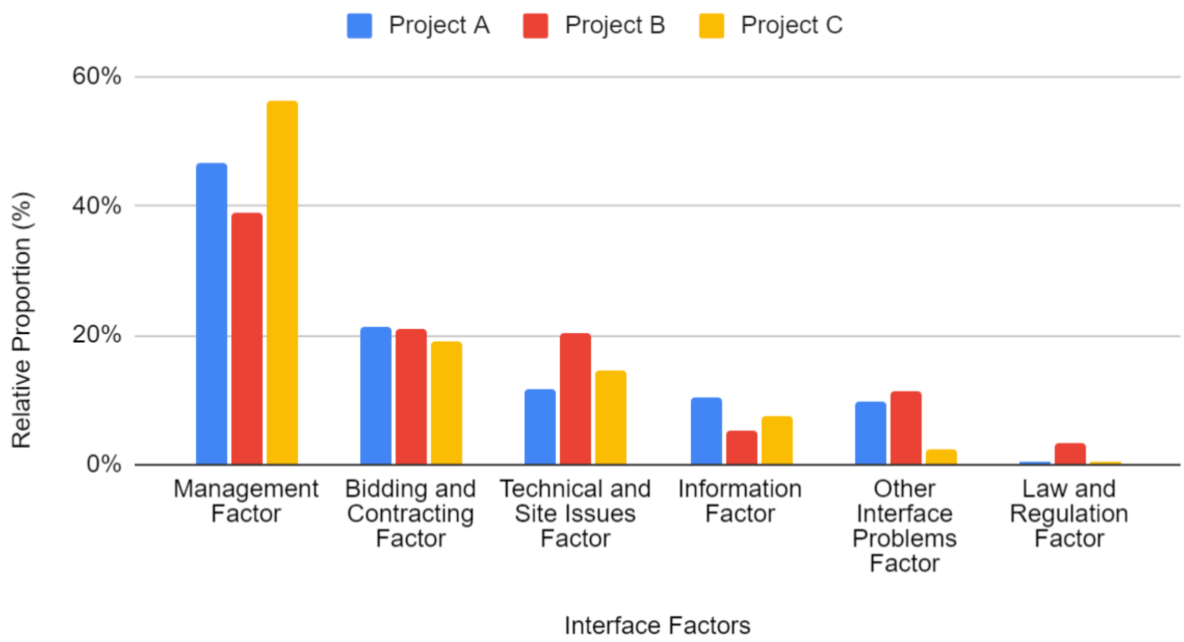

Figure 4: Relative significance of interface factors between projects

A detailed comparison of all interface problems between the different projects could also be made, although it was deemed to be of little value to do so in the present case since the details and inferences would have to have been kept confidential due to the sensitive nature of the case projects under investigation.

6. Discussion

6.1. Relative Significance of Interface Problems

The objective underlying this research, as noted above, was to devise a method that could be used to inform project managers as to which interface problems ought to receive the most attention and resources. Implicit within this objective is the notion that attention and resources invested in the mitigation of interface problems will reduce exposure to project risk (Nooteboom 2004, Bible & Bivins 2019, CII 2014). This concept informed the methodology in terms of assigning risks to interface problems and weighting their relationships. The weighted relationships between risks and interface problems were dependent on the degree to which a given interface problem was considered to have some influence on the project risk, as well as whether there may be some potential for project managers to address the given interface problem. This concept explains two unique characteristics of the results in Table 6 and Figure 2: the significance of the top-rated interface problems and the relative lack of significance of the lowest-rated interface problems.

6.1.1. Interpretation of Most Significant Interface Problems

The top seven interface issues (accounting for 15% of the 47 interface issues) were found to account for about two thirds (65%) of the overall severity values. This is likely due to the fact that these issues are very general in nature and can thus be correlated with a broader variety of project risks due to how widespread they tend to be in contrast to more specific issues. Due to the general scope and lack of specificity of these interface issues, methods of mitigating them are less obvious and, in some instances, irrelevant. For example, the top-rated interface issue, "Inadequate negotiation, communication, and coordination among relevant parties involved in the project", suggests a need for improved negotiation, communication, and coordination skills and structures, but it does not provide any indication as to *how* this might be accomplished. That being said, it does encourage managers to further investigate ways to improve, as well as suggest the need for further investigation in certain areas, such as the benefits of project team partnering workshops/programs.

Examples of interfaces problems for which the mitigation strategies would be considered irrelevant include “Interfaces with other interdependent projects” and “Project nature issues (brownfield vs greenfield)”. Because most newly constructed LRT lines, including the case projects considered herein, are introduced to an existing public transit system, LRT infrastructure is almost always built under brownfield project conditions, where interfaces with interdependent projects are inevitably encountered. While the two interface problems mentioned above were appropriately identified in the results as significant issues in accordance with the objective of this research, highlighting them is not particularly useful, since neither one can realistically be mitigated. In other words, they are inherent interface issues for LRT construction in an existing public transit system and cannot be mitigated.

In general, it is worth noting that, of the 47 interface problems illustrated in Figure 2, the top interface problem, “inadequate negotiation, communication, and coordination”, is by far the most significant interface problem— 40% more important than even the second-most significant interface problem “unclear contract details and poorly written contract”, which is in turn 35% more important than the third-most significant interface problem, “Interfaces with other interdependent projects”.

6.1.2. Interpretation of Least Significant Interface Problems

In accordance with the objective of this research, links between risks and interface problems were only established if the interface problem was considered to have some influence on the project risk. It is also worth considering that a risk register controlled by the city managing a LRT project will typically only track risks retained by the city. This explains why some interface problems were not linked to any risks, since they would have already been transferred or accepted. For example, the interface problems “Limited skills for labour and engineering” and “No proper work packaging design and subcontracting” are shown in Table 6 and Figure 2 to have been assigned zero severity proportion. For those examples, although they likely influence project risks, project managers have little to no control over them, since they are primarily controlled by the project contractor.

The interface problem “type of contracting strategy” is important on LRT projects, particularly in cases in which the LRT vehicles are procured by the city rather than by the contractor, so it should not be surprising that it was ranked among the top 10 interface problems. However, we note that the interface problem “lack of solid contracting strategy vision at early stage of the project” was not assigned any risks, since the *strategy vision* itself was not considered to be the root cause of any risks.

6.2. Relative Significance of Interface Problem Factors

The results in Table 7 and Figure 3 clearly illustrate the high importance of the Management Factor, which accounts for almost half (47%) of the overall severity values. The second- and third-most important interface factors were found to be the Bidding and Contracting Factor (23% severity proportion) and the Technical and Site Issues Factor (14% severity proportion). The dominating importance of the Management Factor observed in this study is in agreement with most of the literature in this area. For example, Ku et al. (2010) concluded that the most important factors in interface management are the experience and coordination/negotiation factors. Huang et al. (2008), meanwhile, identified the three most important interface factors (in order of importance) as coordination, experience, and contract.

6.2.1. Comparison to Weshah’s Findings on Interface Problems and Factors

The 47 interface problems and six interface factors considered in this paper were originally compiled by Weshah et al. (2013), where 135 participants evaluated the impact of the 47 interface problems on interface management performance. Weshah used a six-point Likert scale with the end points being: 1 = negligible to 6 = disastrous. Participants in the questionnaire included individuals from various industries and company types and representing a range of different job titles and years of experience. Weshah presented the results categorized in the aforementioned groups, providing further insight into how one's background influences perception of the impact of a given interface issue on project performance. However, the results of the present study differ from Weshah's in that the present study's results are intended to reflect the impact of interface issues on project performance as a whole, from a single, consolidated perspective. In Weshah's research, on the other hand, multiple sets of results were produced according to various categories (i.e., individual title/role, company type, industry, and years of experience). For example, Figure 5 shows the 6-point Likert rating for each interface factor, organized based on one's title/role, showing the weighted average of all titles/roles combined.

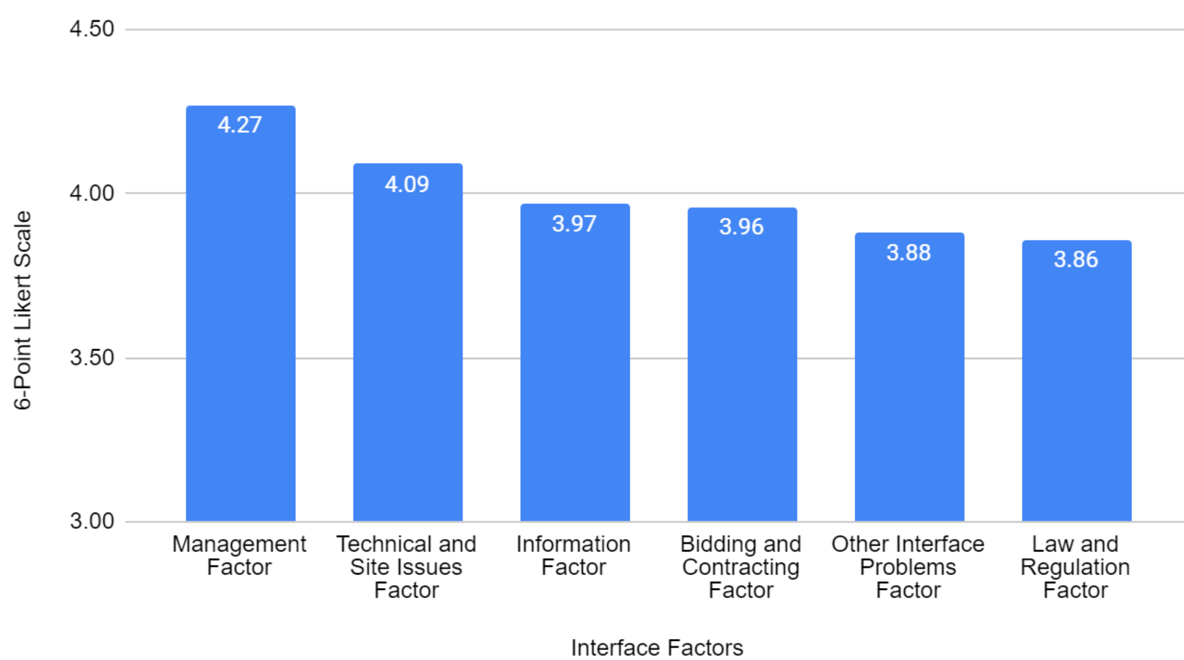

Figure 5: Likert ratings of interface factors (adapted from Weshah (2015))

Comparing Weshah's findings in Figure 5 to the present findings in Figure 3 demonstrates that there is a significant difference between the two sets of results in that the variance is much more significant in the present study compared to Weshah's. This may be attributed to the fact that the participants in Weshah's study all responded individually, and the results were then combined/averaged. This may have levelled out the variance of importance of interface factors. Conversely, in the present study, the data originated from two different sources: (1) risk workshops, in which dozens of participants from various disciplines worked alongside one another to arrive at a consensus for each risk rating, and (2) targeted risk meetings with subject matter experts to discuss select risks within their scope of work. This allowed for every risk to be assessed by those individuals who were best suited to evaluate them (along with all participants' input). As a result, there is likely more opportunity for diverse and varied quantification of risks, which would translate into more varied rankings of interface factors.

Side-by-side comparison between Weshah's findings and the present study is not immediately straight forward since they have differing scales (Weshah's is based on a Likert rating and the present study is based on severity). However, the two data sets can be compared on a common scale if both data sets are normalized using the following formula: *xnormalized = (x – xminimum) / range of x*. The results after normalization are shown in Figure 6.

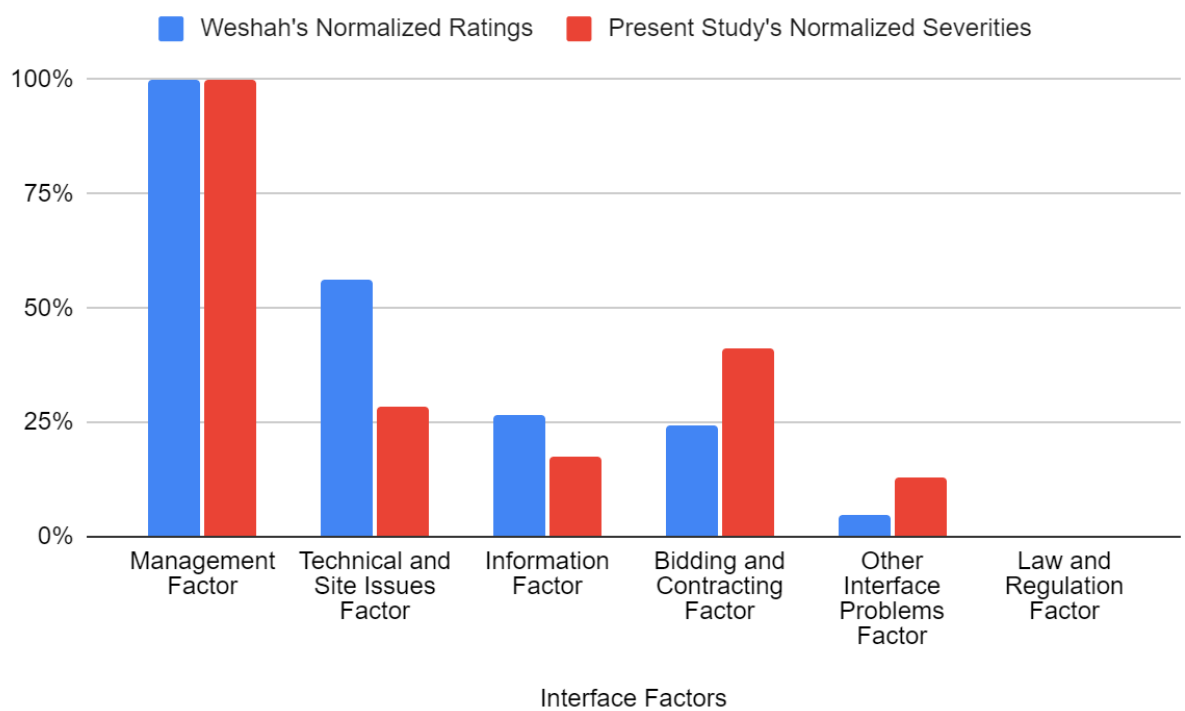

Figure 6: Interface Factor rating comparison between Weshah's study and the present study

Figure 6 demonstrates where the results share commonality and where they differ. In both studies (i.e., Weshah's and the present one), the "Management Factor" is clearly the most important. The remaining factors for both data sets are sequenced the same in terms of relative importance other than the "Bidding and Contracting Factor" which was ranked second in the present study and fourth in Weshah's results. Considering that bidding and contract development stages are when interfaces and potential conflicts are defined at the start of the project, it is logical that this factor would be ranked highly.

6.3. Reliability, Validity, and Study Limitations

The reliability and validity of the inferences made based on this study's results hinge on both the methodology and the data collected.

6.3.1. Reflection on Data Collection

As discussed in Chapter 3, data was obtained from Weshah's (2015) research findings for interface management-related data, while the risk analysis-related data was obtained from real LRT project risk registers. Weshah's 47 interface problems, in turn, were the combined result of an exhaustive literature review and questionnaires responses from 135 industry experts in Alberta, Canada. With regard to the six interface factors established based on the 47 interface problems, Weshah confirmed the reliability of the factor analysis by testing the factors' Cronbach's alpha values, and validated the factors using normality and ANOVA tests. The risk analysis data was obtained from LRT project risk registers; (project risk registers are established through a formal risk management process of risk identification, analysis, mitigation, and ongoing monitoring, and are cyclical in nature). The process of risk identification and quantification that was used for establishing the mentioned risk registers is further detailed in Appendix A.

6.3.2. Reflection on Methodology

Two components of the developed methodology warrant further discussion. First, the process of mapping risks onto one or more of the 47 interface problems was based on the author's own judgment. This means the "lens of the researcher", as described by Creswell & Miller (2000), should be acknowledged in the present case. The author's six years of experience working for a construction management consulting firm, engaged in project controls, risk management, and claims on LRT projects, provided the requisite insight mapping the risks onto the interface problems. Nevertheless, it should be stated that the task of assigning risks to interface problems is an inherently subjective process. The validity of the risk mapping task would have been greater had more people been involved in the process, although that was not a realistic option given the number of possible combinations (nearly 10,000) between risks (over 200) and interface issues (47), which ended up being manually consolidated into approximately 500 links. Both the methodology and the results were verified using face validity—"subjective, nonstatistical judgment that seeks the opinion of non-researchers regarding the validity of a particular study" (Lucko & Rojas, 2009, p. 2). Moreover, this research was presented to a focus group of industry experts who, based on their experience working on LRT projects, provided positive feedback on the reliability of the methodology and the validity of the results.

Second, the process of rating the strength of the links between interface issues and risks was also based on the author's judgment. To test the significance of this process and the extent to which it may have influenced the results, an alternate set of results was produced in which the ratings of the links between interface issues and risks were omitted from the evaluation process altogether (i.e., equal weighting for all links). Figure 7 compares the severity proportion of all 6 interface factors for the original data (assigned weighting) and the levelled data (uniform weighting).

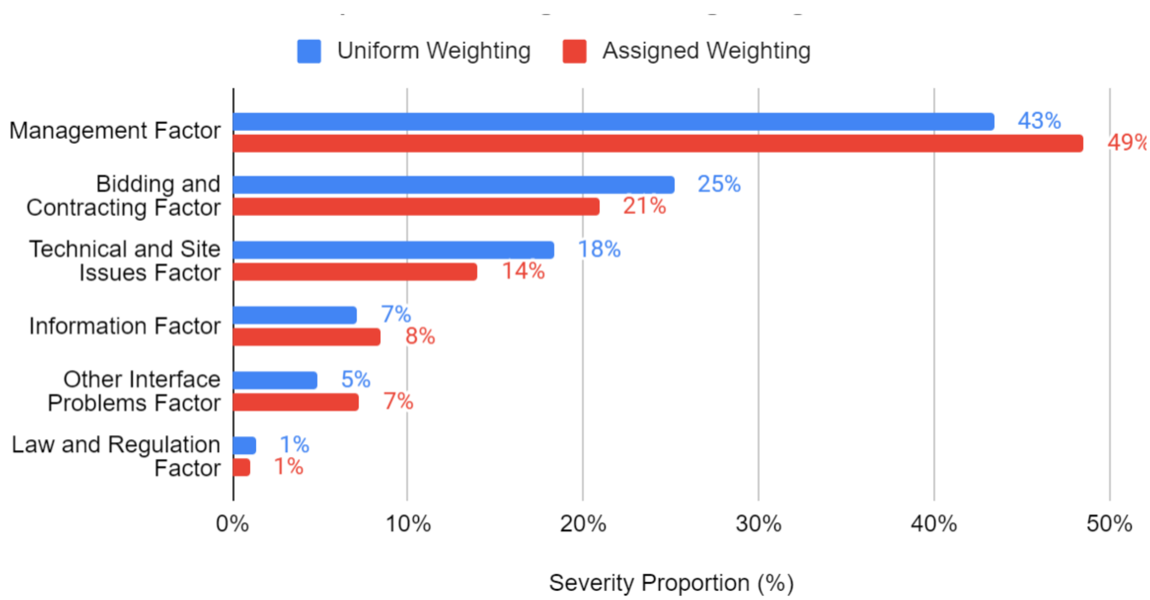

Figure 7: Relative significance of interface factors based on uniform versus assigned weighting

Figure 7 shows the relative strength/weakness of the weightings of the factors. Based on the author's judgment, the "management factor", "information factor", and "other interface problem factor" received stronger weightings, and the "bidding and contracting factor" and "technical and site issues factor" received weaker weightings. Nevertheless, Figure 7 also demonstrates that the process of weighting the links between interface issues and risks did not alter the outcome of the results in terms of the general order of relative significance of interface factors. This finding suggests that any personal bias that may have been at play on the part of the author did not invalidate the results.

7. Conclusion

7.1. Inferences and Contributions

Given the significant impact interface problems have on projects and the lack of consensus among owners as to how best to implement interface management, this research fills a gap by providing a method that informs project managers as to where to focus their efforts and resources to effectively mitigate interface problems and improve project success. From a high-level perspective, the most significant interface factor was found to be the “Management Factor”, followed by ‘Bidding and Contracting Factor”, “Technical and Site Issues Factor”, “Information Factor”, “Other Interface Problems Factor”, with the least significant being the “Law and Regulation Factor”. The 47 interface problems considered in this study were sorted in terms of importance, with “inadequate negotiation, communication, and coordination” clearly being the most important, followed by “unclear contract details and poorly written contract” in second. The key contribution of this research is a unique method that leverages risk assessment data to help understand and comprehensively prioritize the relative importance of interface problems and factors, which serves as a as a useful decision support tool for project managers allocating resources to mitigate interface issues.

7.2. Future Research

The following topics are suggested for future research in this research area:

- researching how to mitigate the top-rated interface factors and problems as identified in this research;
- adapting the presented method by making use of other risk-focused research that has sorted the order of importance of project risks;

- extending the presented method to enable inferences regarding the impact of different project phases and/or different delivery models; and
- adapting the presented method for use in other areas of the construction field.

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Appendix A: Risk Assessment Process

Risk Assessment Process

As the present study heavily relies on pre-existing risk assessment data to indirectly quantify interface issues, this section provides background on the risk identification and quantification process that often occurs on construction projects, including those used in the present study. While the entire risk management process includes (1) risk identification, (2) risk analysis, (3) mitigation action, and (4) monitoring and controlling, this section only addresses the first two steps. The process described below is based on the steps outlined by AbouRizk (2008), which broadly reflects the process used on the projects incorporated into this study.

Preparation

At the start of a project, a risk analyst or risk review team familiarizes themselves with the project by interviewing the owner, design consultant and other involved parties, as well as reviews any pertinent material such as project contracts and designs documents. Additional research may be conducted to further understand the project, and material is gathered in preparation for the risk analysis process. A plan is developed for how the risk assessment process will be carried out.

1. **Risk Identification**

The aim of this step is to identify all the possible risk events that pose a threat to the project (from the owner's point of view). This usually begins with the risk analyst populating a register of risks based on pre-existing checklists that have been developed from past experiences and literature reviews. Although, the register may also draw from decision trees, questionnaires, Delphi technique, HAZOP, and comparisons to other projects. From there, a workshop is held with various participants, facilitated by an independent risk specialist, to further brainstorm and identify new risks unique to the project or anything else not yet considered. The workshops tend to last a day or two and include a wide variety of stakeholder representation from management, engineering, operations, maintenance, communications, etc. During the workshop, every existing and newly-identified risk factor is closely studied to document every possible cause of the risk factor as well as potential impacts to the project. By relying on expert opinion and insights from the various participants, specific impacts to project cost, schedule, and goals are documented.

2. Risk Quantification

Quantifying each risk involves determining the overall significance of each risk, which is best represented in terms of a severity value. Severity accounts for both the expected impact from a risk as well as the likelihood of occurrence based on the following formula:

Severity = likelihood of occurrence of a risk x magnitude of impact

A combination of linguistic terms and numeric values are used to reflect the probability and impact, and the "values to use" (in the formula above) for likelihood and impact are based on a scale of the risk analyst's choosing. For the projects used in the present study, the scales of "values to use" grow exponentially, which allows more discrimination between the terms. These scales come into play when severity is calculated and calibrated to reflect the owner's risk tolerance. The overall quantification process is described in steps below. Note that the exact risk tables used in the present study are not provided for the sake of confidentiality, so generic tables (A1, A2, A3 and A4) are shown below with their own scales.

a) Determine the likelihood of the factor being encountered (e.g. probability, or a subjective descriptor) using Table A1.

Table A1: From AbouRizk (2008) – "Likelihood table for risk analysis" (reprinted with permission)

Linguistic	Explanation	Probability	Low	High	Ordinal [0-100]
Very Likely	Almost certain that it will happen	0.825	65 %	100 %	100
Likely	More than 50-50 chance	0.500	35 %	65 %	50
Somewhat Likely	Less than 50-50 chance	0.250	15 %	35 %	25
Unlikely	Small likelihood but could well happen	0.100	5%	15 %	10
Very Unlikely	Not expected to happen	0.030	1%	5%	3
Extremely Unlikely	Just possible but would be very surprising	0.005	0.0 0%	0.0 1%	1

b) Determine the magnitude of the impact from the encountered risk using Table A2. For the projects used in the present study, a unique impact scale was developed for each type of impact considered, i.e. cost, schedule, and goals. The scales are carefully calibrated to align with the owner's attitudes and values. For example, the risk analyst would start with asking the owner what financial impact would be considered "disastrous" (such as a $100 million loss on a $250 million dollar project). The remaining descriptors and associated monetary impacts are then selected relative to the "disastrous" benchmark. The same process is then used to establish the scale for schedule delays and descriptions of impacts to goals.

Table A2: From AbouRizk (2008) – "Assessment of the magnitude of risk" (reprinted with permission)

Descriptor	Explanation	Value to use
Disastrous	The impact is totally unacceptable to the organization	1000
Severe	Serious threat to the organization, public etc.	100
Substantial	Considerably affects cost	50
Moderate	Moderately affects cost	10
Marginal	Small effect on cost	5
Negligible	Trivial effect on cost	1

c) Determine the overall severity of the factor by multiplying the likelihood (a) by magnitude (b).

d) Group factors based on the overall severity score according to a developed scale, such as in Table A3. There are ranges of severity for each level of risk tolerance, the boundaries for which are arbitrarily, though carefully, set based on the owner's tolerance of risk. The boundaries of the risk severity brackets will vary from owner to owner and from project to project based on their risk tolerance and project conditions. This step is also where the response to each level of risk is documented.

Table A3: From AbouRizk (2008) – "Assessment of the consequence of a risk factor" (reprinted with permission)

Total severity	Category	Response
Over 10,000	Intolerable	Must eliminate or transfer risk, it may jeopardize the entire organization or its cost may be manifold that of the project.
2,500 - 10,000	Critical	Expected cost to the project is unacceptably high, (more than x% of the total project cost). This risk must be eliminated or transferred before proceeding with the project. Attempt to avoid or transfer risk
500 – 2,499	Serious	Expected cost is high compared to total project cost. It probably is cost effective to eliminate or transfer this risk.
100 - 499	Important	Consider eliminating or transferring. If accept then manage proactively.
15-99	Acceptable	Accept and manage
1-14	Negligible	The expected cost of this risk is too small to justify any mitigation effort. Accept and ignore it.

The severity ranges shown in Table A3 are calibrated by carefully evaluating the matrix elements shown in Table A4 (i.e. the combinations of likelihood and impact), and by considering the owner's perception of various ranges of risk tolerance. Table A4 is generated by multiplying the likelihood table with the impact table, and the colours are determined through the calibration process. Calibration is done by evaluating the categories of tolerance in Table A3, and deciding which combinations of likelihood and impact fall under those categories, starting from the most extreme ("intolerable") risks, then working down towards the least significant ("negligible"). Note that the colours reflecting risk tolerance in Table A4 are based on specific tolerances defined in Table A3, which would differ for another owner and for another project.

Table A4: From AbouRizk (2008) – "Risk tolerance matrix" (reprinted with permission)

		Disastrous	Severe	Substantial	Moderate	Marginal	Negligible
		1000	100	50	10	5	1
Very Likely	100	100000	10000	5000	1000	500	100
Likely	50	50000	5000	2500	500	250	50
Somewhat Likely	25	25000	2500	1250	250	125	25
Unlikely	10	10000	1000	500	100	50	10
Very Unlikely	3	3000	300	150	30	15	3
Extremely Unlikely	1	1000	100	50	10	5	1

Through further discussion on each category of risk tolerance, the owner would also reflect on appropriate responses to those levels of risk. Readers are encouraged to review AbouRizk (2008) for a discussion of this topic, which is beyond the scope of the present study.

Appendix B: Raw Data - Interface Factors, Problems, and Risks

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
1	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	35000
2	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	C	C1		1250	6250
3	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Combined	A, C	C1, A1, A37, A38, A42		8250	41250
4	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Separated	A	A2, A44	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2750	13750
5	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	14750
6	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	28500
7	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	City diverges from submittal review procedure leading to a claim from the contractor	4		A	A3	Drivers for this risk also include not understanding project requirements and wrongly endorsing a submittal, not identifying appropriate reviewer in advance, missing something during a review and requiring a change later, or not doing its due diligence during review.	1400	5600
8	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Land expropriation settlement costs exceed initial estimate	5	Separated	A	A4	Communication/negotiation with land development departments in the City, land owners, law offices, as well as prime contractor	1375	6875
9	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Land expropriation settlement costs exceed initial estimate	5	Separated	B	B1		35	175
10	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Land expropriation settlement costs exceed initial estimate	5	Separated	B	B2		750	3750
11	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Land expropriation settlement costs exceed initial estimate	5	Combined	A, B	A4, B1, B2		2160	10800
12	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access (on City-identified property)	3	Separated	A	A5	Communication with land owners, City council, land departments	125	375
13	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access (on City-identified property)	3	Separated	B	B1		35	105
14	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access (on City-identified property)	3	Separated	C	C3		625	1875
15	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed land access (on City-identified property)	3	Combined	A, B, C	A5, B1, C3		785	2355
16	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed, or additional land required	4	Separated	B	B3		125	500
17	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed, or additional land required	4	Separated	C	C4		175	700
18	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed, or additional land required	4	Combined	B, C	C4, B3		300	1200
19	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Unexpected additional drainage requirements	5		A	A6	Communication and monitoring of contractor work enables issues to be dealt with as soon as possible, before the issue escalates	625	3125
20	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Scope changes are requested during construction as a result of political/public pressure	5	Separated	A	A7	Communication with City Council	625	3125
21	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Scope changes are requested during construction as a result of political/public pressure	5	Separated	B	B4	Communication with City Council	35	175
22	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Scope changes are requested during construction as a result of political/public pressure	5	Separated	C	C5	Communication with City Council	2750	13750
23	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Scope changes are requested during construction as a result of political/public pressure	5	Combined	A, B, C	A7, B4, C5	Communication with City Council	3410	17050
24	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	System element does not meet project vision	5		A	A8	Communication is key for ensuring project vision is delivered	625	3125
25	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Poor model integration between traffic operations and LRT operations	5		A	A9	Individual and combined commnication with traffic operations, LRT contractor, and the public	385	1925
26	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Trackwork stray current requires city involvment to mitigate/repair damages	3		A	A10	Communication through submittal reviews	125	375
27	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed City led utility work delays LRT contractor	5	Separated	A	A11	Communication with utility companies and LRT contractor	625	3125
28	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed City led utility work delays LRT contractor	5	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	13875
29	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Delayed City led utility work delays LRT contractor	5	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	17000

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
30	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Relationship between City and LRT contractor is not maintained	5		A	A12	Quality and open communication facilitates a healthy relationship	125	625
31	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Construction inconveniences lead to public opposition	5	Separated	A	A13	Communications with the public and City Council	625	3125
32	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Construction inconveniences lead to public opposition	5	Separated	C	C7	Communications with the public and City Council	2750	13750
33	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Construction inconveniences lead to public opposition	5	Combined	A, C	A13, C7	Communications with the public and City Council	3375	16875
34	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	City transfers snow/ice onto infrastructure during construction	5		A	A14	Communication with City departments	125	625
35	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	LRT contractor lacks transparency or adequate public service	5		A	A15	Converying expectations to LRT contractor, and as-needed communications with the public	1250	6250
36	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	City fails to fulfill commitments to adjacent landowners	5		A	A16	Communications with City Council regarding commitments made to public, and communications with public directly	1250	6250
37	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Public expectations are not met despite design/construction being compliant with contract	5	Separated	A	A17	Communications with public, LRT contractor	1250	6250
38	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Public expectations are not met despite design/construction being compliant with contract	5	Separated	C	C8, C39, C37	Communications with public, LRT contractor	1440	7200
39	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Public expectations are not met despite design/construction being compliant with contract	5	Combined	A, C	A17, C8	Communications with public, LRT contractor	2690	13450
40	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Design inadequacies require additional safety items that undermine City vision	5		A	A18	Communication with LRT contractor as safety concerns arise	300	1500
41	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	LRV design/supply delays Service Commencement	4	Separated	A	A19	Communication with LRV designer/supplier, and communication between interconnect team partners (e.g. infrastructure design and LRV design)	2750	11000
42	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	LRV design/supply delays Service Commencement	4	Separated	C	C9, C30, C38, C41, C42	Communication with LRV designer/supplier, and communication between interconnect team partners (e.g. infrastructure design and LRV design)	3285	13140
43	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	LRV design/supply delays Service Commencement	4	Combined	A, C	A19, C9, C30, C38, C41, C42	Communication with LRV designer/supplier, and communication between interconnect team partners (e.g. infrastructure design and LRV design)	6035	24140
44	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contractor delivers sub-par quality of general construction works	5	Separated	A	A20	Communication with contractor, City Council, public	10000	50000
45	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contractor delivers sub-par quality of general construction works	5	Separated	C	C10	Communication with contractor, City Council, public	1400	7000
46	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contractor delivers sub-par quality of general construction works	5	Combined	A, C	A20, C10	Communication with contractor, City Council, public	11400	57000
47	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Important construction schedule milestone deadlines are missed	4		A	A21	Communication with LRT contractor and third parties that could be impacted be delayed milestones	3750	15000
48	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Inadequate systems and/or operations input into the design and construction	4		A	A22	Communications with LRT contractor to encourage involvement of systems/operations team	8250	33000
49	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Public interference with construction by blockade, embargo, protest, etc.	5		A	A23	Communications with the public, police and other secutity firms	175	875
50	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Combined	A, B	A24, B5	Communications with government environmental agencies, as well as internal and external monitors	15125	15125
51	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	A	A24	Communications with government environmental agencies, as well as internal and external monitors	13750	13750
52	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	B	B5	Communications with government environmental agencies, as well as internal and external monitors	625	625
53	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	C	C11, C31	Communications with government environmental agencies, as well as internal and external monitors	750	750
54	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Fill material is not readily available	3		B	B6	Fill material sourcing can be established/confirmed prior or post start of construction with suppliers	1250	3750
55	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Proposed alignment must change to accomodate existing utility, or utility has to be relocated	2		B	B7	Communication and negotiation with utility owners may result in win-win solution, decreased likelihood of needing to change alignment, and/or minimize impact if the utility must be moved. Communications with government officials minimizes long term impact.	11212	22424
56	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Noise levels of LRT exceed noise allowances for residents, so noise walls must be added to the scope of work	1	Separated	B	B8, B15	Communication with residents to set expectations around noise levels and noise wall construction	1300	1300
57	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Noise levels of LRT exceed noise allowances for residents, so noise walls must be added to the scope of work	1	Separated	C	C12	Communication with property owners	100	100

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
58	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Noise levels of LRT exceed noise allowances for residents, so noise walls must be added to the scope of work	1	Combined	B, C	C12, B8, B15	Communication with property owners	1400	1400
59	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	2	Separated	B	B9	Communications with federal, environmental, rail/construction industry groups	3750	7500
60	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	2	Separated	C	C13	Communications with federal, environmental, rail/construction industry groups	385	770
61	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	2	Combined	B, C	B9, C13	Communications with federal, environmental, rail/construction industry groups	4135	8270
62	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Additional design/construction measures required while seeking approval from First Nations groups	4		B	B10	Communications with First Nations groups	125	500
63	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Additional measures required to maintain, adjust, stage, detour, etc. the existing bus system during construction	3		B	B11	Communicate/coordinate with alternate transit system operators	7000	21000
64	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	4		B	B12	Communication with proponents to keep them interested	10000	40000
65	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Interference and/or required accomodations/negotiations for third-part events, such as festivals, sport events, markets, etc.	5		C	C14		35	175
66	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Impacts from having to integrate with other LRT projects	3		C	C15	There is a limit to how much communication can help	30000	90000
67	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Impacts on LRV contract from having to integrate with other LRT projects	3		C	C16	There is a limit to how much communication can help	13750	41250
68	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Contract changes to accomodate LRV operations and maintenance improvements	2		C	C17	Communications required to gather info and relay to relevant parties	1250	2500
69	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	Failing to fulfill commitments to targeted group	3		C	C18		175	525
70	1	Management Factor	Lack of enough negotiation and communication and coordination among relevant parties involved in the project.	LRV Supplier faces Quality Issues during Testing and Commissioning	1		C	C19	Communication with public is not a limitation/problem, although it is one of the few mitigations	385	385
71	2	Management Factor	Financial difficulties.	Insufficient City resources or budget	5		A	A25, A36, A39		1625	8125
72	2	Management Factor	Financial difficulties.	Land expropriation settlement costs exceed initial estimate	1	Separated	A	A4	Financial difficulties add to this risk if insufficient contingnecy funds were allocated	1375	1375
73	2	Management Factor	Financial difficulties.	Land expropriation settlement costs exceed initial estimate	1	Separated	B	B1		35	35
74	2	Management Factor	Financial difficulties.	Land expropriation settlement costs exceed initial estimate	1	Separated	B	B2		750	750
75	2	Management Factor	Financial difficulties.	Land expropriation settlement costs exceed initial estimate	1	Combined	A, B	A4, B1, B2		2160	2160
76	3	Management Factor	Poor decision making.	Land expropriation settlement costs exceed initial estimate	1	Separated	A	A4	Decisions relating to which lands and how much are necessary, or when to close accesses, or when to expect tenants to leave prior to demolition	1375	1375
77	3	Management Factor	Poor decision making.	Land expropriation settlement costs exceed initial estimate	1	Separated	B	B1		35	35
78	3	Management Factor	Poor decision making.	Land expropriation settlement costs exceed initial estimate	1	Separated	B	B2		750	750
79	3	Management Factor	Poor decision making.	Land expropriation settlement costs exceed initial estimate	1	Combined	A, B	A4, B1, B2		2160	2160
80	3	Management Factor	Poor decision making.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	A	A7	Refers specifically to potential poor decisions relating to scope and concept	625	1250
81	3	Management Factor	Poor decision making.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	B	B4	Refers specifically to potential poor decisions relating to scope and concept	35	70
82	3	Management Factor	Poor decision making.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	C	C5	Refers specifically to potential poor decisions relating to scope and concept	2750	5500
83	3	Management Factor	Poor decision making.	Scope changes are requested during construction as a result of political/public pressure	2	Combined	A, B, C	A7, B4, C5	Refers specifically to potential poor decisions relating to scope and concept	3410	6820
84	3	Management Factor	Poor decision making.	City directs LRT contractor to rectify perceived deficiencies, which are ultimately deemed unnecessary in court	5		A	A26	Pending a cost/benefit analysis of whether to direct LRT contractor	175	875
85	3	Management Factor	Poor decision making.	Relationship between City and LRT contractor is not maintained	2		A	A12	Decisions relating to supervision, changes in management, leadership, resourcing, taking responsibility, etc	125	250
86	3	Management Factor	Poor decision making.	Delayed land access (on City-identified property)	3	Separated	A	A5	Decisions for when to make lands available to LRT contractor based on estimated access requirement date	125	375
87	3	Management Factor	Poor decision making.	Delayed land access (on City-identified property)	3	Separated	B	B1		35	105
88	3	Management Factor	Poor decision making.	Delayed land access (on City-identified property)	3	Separated	C	C3		625	1875
89	3	Management Factor	Poor decision making.	Delayed land access (on City-identified property)	3	Combined	A, B, C	A5, B1, C3		785	2355

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
90	3	Management Factor	Poor decision making.	If project construction is staged incorrectly, ridership targets won't be met, along with lost revenue, using more busses than planned, and implementing workaround solutions	1		B	B13	Decision making by both or either parties (contractor and City)	10000	10000
91	3	Management Factor	Poor decision making.	Changes to LRT contract leading to knock-on effects	3		C	C20	Knock-on effects may not have been comprehensively considered	1375	4125
92	4	Technical and Site Issues Factor	Limited skills for labour and engineering.				#N/A				0
93	5	Technical and Site Issues Factor	Materials procurement problems.	Fill material is not readily available	5		B	B6	Fill material sourcing can be established/confirmed prior or post start of construction with suppliers	1250	6250
94	6	Technical and Site Issues Factor	Construction process problems.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	A	A27, A40, A41, A43, A43	Latent defects can require unexpected and unique construction processes to remedy encountered problems. Moreso for the contractor to manage.	6500	13000
95	6	Technical and Site Issues Factor	Construction process problems.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	C	C21, C32	Latent defects can require unexpected and unique construction processes to remedy encountered problems. Moreso for the contractor to manage.	1010	2020
96	6	Technical and Site Issues Factor	Construction process problems.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Combined	A, C	C21, C32, A27, A40, A41, A43	Latent defects can require unexpected and unique construction processes to remedy encountered problems. Moreso for the contractor to manage.	7510	15020
97	6	Technical and Site Issues Factor	Construction process problems.	Unidentified underground infrastructure conflicts	1		A	A28	Claims made for having to remove/relocate infrastructure. Construction process could be impacted, although are usually relatively straight forward	2750	2750
98	6	Technical and Site Issues Factor	Construction process problems.	Damage to reputation if contractor causes damage to third party property	4		A	A29	Construction process related which can/should be monitored	385	1540
99	6	Technical and Site Issues Factor	Construction process problems.	Unexpected geotechnical conditions encountered, increasing construction costs	2		B	B14	How unexpected conditions are dealt with	1250	2500
100	6	Technical and Site Issues Factor	Construction process problems.	Additional measures required to maintain, adjust, stage, detour, etc. the existing bus system during construction	2		B	B11		7000	14000
101	6	Technical and Site Issues Factor	Construction process problems.	Additional land requirments	4		C	C22	Usually constrction related, not management related	750	3000
102	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	A	A27, A41, A43, A43	How engineering processes are implemented/managed influences the impact of encountered problems. More so for the contractor.	5750	11500
103	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	C	C21, C32	How engineering processes are implemented/managed influences the impact of encountered problems. More so for the contractor.	1010	2020
104	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Combined	A, C	C21, C32, A27, , A41, A43, A43	How engineering processes are implemented/managed influences the impact of encountered problems. More so for the contractor.	6760	13520
105	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Unexpected additional drainage requirements	3		A	A6	Construction issues come up relating to deficiencies with exisiting drainage tie in points	625	1875
106	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Poor model integration between traffic operations and LRT operations	5		A	A9	Critical review of design and whether requirements are being met	385	1925
107	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Sloped ground collapsing due to natural cause or LRT/third party construction	5		A	A30	Risk is managed by LRT contractor	385	1925
108	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Trackwork stray current requires city involvment to mitigate/repair damages	3		A	A10	Interfaces potentially affected by stray current, and interface with LRT contractor	125	375
109	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Design inadequacies require additional safety items that undermine City vision	4		A	A18	Design of safety vs performance	300	1200
110	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Delayed land access (on City-identified property)	3	Separated	A	A5	Decisions for when to make lands available to LRT contractor based on estimated access requirement date	125	375
111	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Delayed land access (on City-identified property)	3	Separated	B	B1		35	105
112	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Delayed land access (on City-identified property)	3	Separated	C	C3		625	1875
113	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Delayed land access (on City-identified property)	3	Combined	A, B, C	A5, B1, C3		785	2355
114	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	LRV design/supply delays Service Commencement	4	Separated	A	A19		2750	11000
115	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	LRV design/supply delays Service Commencement	4	Separated	C	C9, C30, C38, C41, C42		3285	13140
116	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	LRV design/supply delays Service Commencement	4	Combined	A, C	A19, C9, C30, C38, C41, C42		6035	24140
117	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Proposed alignment must change to accomodate existing utility, or utility has to be relocated	1		B	B7	Engineering design and discussion relates to utility allowances	11212	11212

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
118	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Private property adjacent to tracks with noise/vibration sensitivities (e.g. recording studio, scientific labs) require aditional design mitigations and/or must be relocated	4		B	B15	Engineering approach to vibration/sound dampening is critical for sensitive properties	1250	5000
119	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Where private land is required although not realistically possible to expropriate, additional mitigation measures would be required to minimize impact, or costly redesign to avoid any/all interuption	4		B	B16	Engineering process must be closely coordinated with land owner	3000	12000
120	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Impacts from having to integrate with other LRT projects	2		C	C15	Spec alignment and transfer not straight forward	30000	60000
121	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Impacts on LRV contract from having to integrate with other LRT projects	2		C	C16	Spec alignment and transfer not straight forward	13750	27500
122	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Contract changes to accomodate LRV operations and maintenance improvements	2		C	C17	Challenge in integrating operations improvements into designs	1250	2500
123	7	Technical and Site Issues Factor	Engineering process problems related to interfaces.	Changes to LRT contract leading to knock-on effects	2		C	C20	Engineering impacts (cause and effects)	1375	2750
124	8	Technical and Site Issues Factor	Project site issues.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Separated	A	A27, A40, A41, A43, A43	Project site issues create implicit concern for latent defects in brown field construction. Little to mitigate other than concept plan, and contract agreements for how issues are managed.	6500	6500
125	8	Technical and Site Issues Factor	Project site issues.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Separated	C	C21, C32	Project site issues create implicit concern for latent defects in brown field construction. Little to mitigate other than concept plan, and contract agreements for how issues are managed.	1010	1010
126	8	Technical and Site Issues Factor	Project site issues.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Combined	A, C	C21, C32, A27, A40, A41, A43	Project site issues create implicit concern for latent defects in brown field construction. Little to mitigate other than concept plan, and contract agreements for how issues are managed.	7510	7510
127	8	Technical and Site Issues Factor	Project site issues.	Unexpected additional drainage requirements	3		A	A6	Construction issues come up relating to deficiencies with exisiting drainage tie in points	625	1875
128	8	Technical and Site Issues Factor	Project site issues.	Unidentified underground infrastructure conflicts	1		A	A28	Claims made for having to remove/relocate infrastructure. Construction process could be impacted, although are usually relatively straight forward	2750	2750
129	8	Technical and Site Issues Factor	Project site issues.	Damage to reputation if contractor causes damage to third party property	4		A	A29	Project Site issues relating to proximity to third party property	385	1540
130	8	Technical and Site Issues Factor	Project site issues.	Unexpected geotechnical conditions encountered, increasing construction costs	3		B	B14	Project site issues related to geotechnical issues	1250	3750
131	8	Technical and Site Issues Factor	Project site issues.	Proposed alignment must change to accomodate existing utility, or utility has to be relocated	1		B	B7		11212	11212
132	8	Technical and Site Issues Factor	Project site issues.	Additional land requirments	3		C	C22	Usually construction related, not management related	750	2250
133	9	Information Factor	Information problems.	City diverges from submittal review procedure leading to a claim from the contractor	4		A	A3	Drivers for this risk also include not understanding project requirements and wrongly endorsing a submittal, not identifying appropriate reviewer in advance, missing something during a review and requiring a change later, or not doing its due diligence during review.	1400	5600
134	9	Information Factor	Information problems.	Contract changes to accomodate LRV operations and maintenance improvements	2		C	C17	Information tracking and distribution is key	1250	2500
135	9	Information Factor	Information problems.	Changes to LRT contract leading to knock-on effects	2		C	C20	Information systems	1375	2750
136	10	Management Factor	Lack of project management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	4	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	28000
137	10	Management Factor	Lack of project management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	4	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	500
138	10	Management Factor	Lack of project management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	4	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	28500
139	10	Management Factor	Lack of project management.	Unidentified underground infrastructure conflicts	2		A	A28	Owner involvement could help, depending on the contract type	2750	5500
140	10	Management Factor	Lack of project management.	City diverges from submittal review procedure leading to a claim from the contractor	2		A	A3	Drivers for this risk also include not understanding project requirements and wrongly endorsing a submittal, not identifying appropriate reviewer in advance, missing something during a review and requiring a change later, or not doing its due diligence during review.	1400	2800
141	10	Management Factor	Lack of project management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	A	A2, A44	Project Management is required in order to ensure coordination between parties is carried out	2750	11000
142	10	Management Factor	Lack of project management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	11800

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
143	10	Management Factor	Lack of project management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	22800
144	10	Management Factor	Lack of project management.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	A	A31	Leadership and guidance over relevant parties is required to relay proactive and safe practices that avoid risk take back	625	1250
145	10	Management Factor	Lack of project management.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	C	C23, C33	Leadership and guidance over relevant parties is required to relay proactive and safe practices that avoid risk take back	1010	2020
146	10	Management Factor	Lack of project management.	Risk transferred back to City due to construed City involvement outside contract	2	Combined	A, C	A31, C23, C33	Leadership and guidance over relevant parties is required to relay proactive and safe practices that avoid risk take back	1635	3270
147	10	Management Factor	Lack of project management.	System element does not meet project vision	2		A	A8	Project Management is required for establishing clear expecattions from project team, including how to handle system element reviews	625	1250
148	10	Management Factor	Lack of project management.	Poor model integration between traffic operations and LRT operations	2		A	A9	Project management is needed to oversee/initiate coordination of parties, and make as-needed adjustments to contract	385	770
149	10	Management Factor	Lack of project management.	Delayed City led utility work delays LRT contractor	3	Separated	A	A11	Management must prioritize coordination and communication with utility companies	625	1875
150	10	Management Factor	Lack of project management.	Delayed City led utility work delays LRT contractor	3	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	8325
151	10	Management Factor	Lack of project management.	Delayed City led utility work delays LRT contractor	3	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	10200
152	10	Management Factor	Lack of project management.	Public expectations are not met despite design/construction being compliant with contract	1	Separated	A	A17	PProject Management can evaluate the situation for direction	1250	1250
153	10	Management Factor	Lack of project management.	Public expectations are not met despite design/construction being compliant with contract	1	Separated	C	C8, C39, C37	Communications with public, LRT contractor	1440	1440
154	10	Management Factor	Lack of project management.	Public expectations are not met despite design/construction being compliant with contract	1	Combined	A, C	A17, C8	Communications with public, LRT contractor	2690	2690
155	10	Management Factor	Lack of project management.	LRV design/supply delays Service Commencement	4	Separated	A	A19	Oversight throughout LRV design/manufacturing	2750	11000
156	10	Management Factor	Lack of project management.	LRV design/supply delays Service Commencement	4	Separated	C	C9, C30, C38, C41, C42	Oversight throughout LRV design/manufacturing	3285	13140
157	10	Management Factor	Lack of project management.	LRV design/supply delays Service Commencement	4	Combined	A, C	A19, C9, C30, C38, C41, C42	Oversight throughout LRV design/manufacturing	6035	24140
158	10	Management Factor	Lack of project management.	Contractor delivers sub-par quality of general construction works	3	Separated	A	A20	Active project mamagement is required for initiating construction monitoring, inspection, and reporting of deficiencies	10000	30000
159	10	Management Factor	Lack of project management.	Contractor delivers sub-par quality of general construction works	3	Separated	C	C10	Communication with contractor, City Council, public	1400	4200
160	10	Management Factor	Lack of project management.	Contractor delivers sub-par quality of general construction works	3	Combined	A, C	A20, C10	Communication with contractor, City Council, public	11400	34200
161	10	Management Factor	Lack of project management.	Important construction schedule milestone deadlines are missed	2		A	A21	Monitoring progress and having plans for schedule slippage	3750	7500
162	10	Management Factor	Lack of project management.	Inadequate systems and/or operations input into the design and construction	2		A	A22	Proactive measures to facilitate the involvement of systems/operations personnel	8250	16500
163	10	Management Factor	Lack of project management.	Damage to reputation if contractor causes damage to third party property	2		A	A29	Project Management is required to initiate construction site monitoring, as well as investigation post damage	385	770
164	10	Management Factor	Lack of project management.	Contract changes to accomodate LRV operations and maintenance improvements	1		C	C17	Attention and prioritization reqired for integration	1250	1250
165	10	Management Factor	Lack of project management.	Failing to fulfill commitments to targeted group	3		C	C18		175	525
166	11	Information Factor	Lack of IM system.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	35000
167	11	Information Factor	Lack of IM system.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	625
168	11	Information Factor	Lack of IM system.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	35625
169	11	Information Factor	Lack of IM system.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	A	A2, A44	Project Management is required in order to ensure coordination between parties is carried out	2750	11000
170	11	Information Factor	Lack of IM system.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	11800
171	11	Information Factor	Lack of IM system.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	22800
172	11	Information Factor	Lack of IM system.	Land expropriation settlement costs exceed initial estimate	3	Separated	A	A4	An IM system would highlight important departments within the City where communication must be maintained	1375	4125
173	11	Information Factor	Lack of IM system.	Land expropriation settlement costs exceed initial estimate	3	Separated	B	B1		35	105

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
174	11	Information Factor	Lack of IM system.	Land expropriation settlement costs exceed initial estimate	3	Separated	B	B2		750	2250
175	11	Information Factor	Lack of IM system.	Land expropriation settlement costs exceed initial estimate	3	Combined	A, B	A4, B1, B2		2160	6480
176	11	Information Factor	Lack of IM system.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed	3	Separated	B	B3		125	375
177	11	Information Factor	Lack of IM system.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed	3	Separated	C	C4		175	525
178	11	Information Factor	Lack of IM system.	Earmarked temporary land use (construction laydown/storage/access) no longer available when needed, or additional land required	4	Combined	B, C	C4, B3		300	1200
179	11	Information Factor	Lack of IM system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	A	A7	Interface awareness with public and city council	625	1875
180	11	Information Factor	Lack of IM system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	B	B4	Refers specifically to potential poor decisions relating to scope and concept	35	105
181	11	Information Factor	Lack of IM system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	C	C5	Refers specifically to potential poor decisions relating to scope and concept	2750	8250
182	11	Information Factor	Lack of IM system.	Scope changes are requested during construction as a result of political/public pressure	3	Combined	A, B, C	A7, B4, C5	Refers specifically to potential poor decisions relating to scope and concept	3410	10230
183	11	Information Factor	Lack of IM system.	Poor model integration between traffic operations and LRT operations	3		A	A9	Thorough and ongoing consideration for this interface is required	385	1155
184	11	Information Factor	Lack of IM system.	Sloped ground collapsing due to natural cause or LRT/third party construction	4		A	A30	Project team must be aware of and review construction work being completed nearby	385	1540
185	11	Information Factor	Lack of IM system.	Delayed City led utility work delays LRT contractor	2	Separated	A	A11	An IM system would highlight key utility works that need to be actively monitored	625	1250
186	11	Information Factor	Lack of IM system.	Delayed City led utility work delays LRT contractor	2	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	5550
187	11	Information Factor	Lack of IM system.	Delayed City led utility work delays LRT contractor	2	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	6800
188	11	Information Factor	Lack of IM system.	LRV design/supply delays Service Commencement	4	Separated	A	A19	Interface between City, infrastructure/systems contractor, and LRV designer/supplier	2750	11000
189	11	Information Factor	Lack of IM system.	LRV design/supply delays Service Commencement	4	Separated	C	C9, C30, C38, C41, C42	Interface between City, infrastructure/systems contractor, and LRV designer/supplier	3285	13140
190	11	Information Factor	Lack of IM system.	LRV design/supply delays Service Commencement	4	Combined	A, C	A19, C9, C30, C38, C41, C42	Interface between City, infrastructure/systems contractor, and LRV designer/supplier	6035	24140
191	11	Information Factor	Lack of IM system.	Inadequate systems and/or operations input into the design and construction	3		A	A22	IM system would increase awareness of this interface and what it requires	8250	24750
192	11	Information Factor	Lack of IM system.	Additional measures required to maintain, adjust, stage, detour, etc. the existing bus system during construction	3		B	B11		7000	21000
193	11	Information Factor	Lack of IM system.	Interference and/or required accomodations/negotiations for third-part events, such as festivals, sport events, markets, etc.	5		C	C14		385	1925
194	11	Information Factor	Lack of IM system.	Contract changes to accomodate LRV operations and maintenance improvements	2		C	C17	Early and ongoing management of this interface must be maintained	1250	2500
195	11	Information Factor	Lack of IM system.	Failing to fulfill commitments to targeted group	5		C	C18	IM system would make this priority more visible	175	875
196	12	Management Factor	Planning and scheduling problems.	Insufficient City resources or budget	3		A	A25, A36, A39	Refers to resource planning for this risk	1625	4875
197	12	Management Factor	Planning and scheduling problems.	Land expropriation settlement costs exceed initial estimate	3	Separated	A	A4	Timing for when to obtain access to lands must be scheduled according to planned/estimated construction progress	1375	4125
198	12	Management Factor	Planning and scheduling problems.	Land expropriation settlement costs exceed initial estimate	3	Separated	B	B1		35	105
199	12	Management Factor	Planning and scheduling problems.	Land expropriation settlement costs exceed initial estimate	3	Separated	B	B2		750	2250
200	12	Management Factor	Planning and scheduling problems.	Land expropriation settlement costs exceed initial estimate	3	Combined	A, B	A4, B1, B2		2160	6480
201	12	Management Factor	Planning and scheduling problems.	Delayed City led utility work delays LRT contractor	4	Separated	A	A11	The City's efforts to monitor utility works and LRT works simultaneously means time conflicts can be avoided	625	2500
202	12	Management Factor	Planning and scheduling problems.	Delayed City led utility work delays LRT contractor	4	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	11100
203	12	Management Factor	Planning and scheduling problems.	Delayed City led utility work delays LRT contractor	4	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	13600
204	12	Management Factor	Planning and scheduling problems.	Delayed land access (on City-identified property)	4	Separated	A	A5	Timing for when to obtain access to lands must be scheduled according to planned/estimated construction progress	125	500

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
205	12	Management Factor	Planning and scheduling problems.	Delayed land access (on City-identified property)	4	Separated	B	B1		35	140
206	12	Management Factor	Planning and scheduling problems.	Delayed land access (on City-identified property)	4	Separated	C	C3		625	2500
207	12	Management Factor	Planning and scheduling problems.	Delayed land access (on City-identified property)	4	Combined	A, B, C	A4, B1, C3		785	3140
208	12	Management Factor	Planning and scheduling problems.	Important construction schedule milestone deadlines are missed	1		A	A21	Scheduling construction parallel to LRT contractor's efforts enhances understanding	3750	3750
209	12	Management Factor	Planning and scheduling problems.	LRV design/supply delays Service Commencement	2	Separated	A	A19	Plan and schedule interfaces where applicable for the City	2750	5500
210	12	Management Factor	Planning and scheduling problems.	LRV design/supply delays Service Commencement	2	Separated	C	C9, C30, C38, C41, C42	Plan and schedule interfaces where applicable for the City	3285	6570
211	12	Management Factor	Planning and scheduling problems.	LRV design/supply delays Service Commencement	2	Combined	A, C	A19, C9, C30, C38, C41, C42	Plan and schedule interfaces where applicable for the City	6035	12070
212	12	Management Factor	Planning and scheduling problems.	Impacts from having to integrate with other LRT projects	1		C	C15	Planning and schedling may have been completed, althogh may not have accounted for worst-case scenarios	30000	30000
213	12	Management Factor	Planning and scheduling problems.	Impacts on LRV contract from having to integrate with other LRT projects	1		C	C16	Planning and schedling may have been completed, althogh may not have accounted for worst-case scenarios	13750	13750
214	13	Information Factor	Type of organization structure, for example matrix organization increases interface points.	Relationship between City and LRT contractor is not maintained	2		A	A12	Organization structure across parties shlould be calibrated to what works best for the individuals/teams at the time	125	250
215	14	Management Factor	Interfaces with other interdependent projects.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	35000
216	14	Management Factor	Interfaces with other interdependent projects.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	625
217	14	Management Factor	Interfaces with other interdependent projects.	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	35625
218	14	Management Factor	Interfaces with other interdependent projects.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	A	A2, A44		2750	11000
219	14	Management Factor	Interfaces with other interdependent projects.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	11800
220	14	Management Factor	Interfaces with other interdependent projects.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	4	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	22800
221	14	Management Factor	Interfaces with other interdependent projects.	Sloped ground collapsing due to natural cause or LRT/third party construction	3		A	A30	Project team must be aware of and review construction work being completed nearby	385	1155
222	14	Management Factor	Interfaces with other interdependent projects.	Delayed City led utility work delays LRT contractor	5	Separated	A	A11		625	3125
223	14	Management Factor	Interfaces with other interdependent projects.	Delayed City led utility work delays LRT contractor	5	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	13875
224	14	Management Factor	Interfaces with other interdependent projects.	Delayed City led utility work delays LRT contractor	5	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	17000
225	14	Management Factor	Interfaces with other interdependent projects.	Impacts from having to integrate with other LRT projects	3		C	C15	This is the core of the problem	30000	90000
226	14	Management Factor	Interfaces with other interdependent projects.	Impacts from having to integrate with other LRT projects	3		C	C16	This is the core of the problem	13750	41250
227	14	Management Factor	Interfaces with other interdependent projects.	Changes to LRT contract leading to knock-on effects	4		C	C20	Knock-on effects more likely to occur with more interfaces	1375	5500
228	15	Information Factor	Undefined reporting structure and responsibilities.	City diverges from submittal review procedure leading to a claim from the contractor	4		A	A3	On a more micro level, managing the submittal review procedue must be properly planned,scheduled, and monitored	1400	5600
229	15	Information Factor	Undefined reporting structure and responsibilities.	Risk transferred back to City due to construed City involvement outside contract	3	Separated	A	A31	Clear reporting structures and responsibilities ensures correspondence with prime contractor follows standard procedures as per the contract	625	1875
230	15	Information Factor	Undefined reporting structure and responsibilities.		3	Separated	C	C23, C33	Clear reporting structures and responsibilities ensures correspondence with prime contractor follows standard procedures as per the contract	1010	3030
231	15	Information Factor	Undefined reporting structure and responsibilities.		3	Combined	A, C	A31, C23, C33	Clear reporting structures and responsibilities ensures correspondence with prime contractor follows standard procedures as per the contract	1635	4905
232	15	Information Factor	Undefined reporting structure and responsibilities.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	A	A7	Clear reporting structures allow new information to quickly and correctly travel to the necessary roles, including those that communicate directly with city council	625	1250
233	15	Information Factor	Undefined reporting structure and responsibilities.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	B	B4	Clear reporting structures allow new information to quickly and correctly travel to the necessary roles, including those that communicate directly with city council	35	70

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
234	15	Information Factor	Undefined reporting structure and responsibilities.	Scope changes are requested during construction as a result of political/public pressure	2	Separated	C	C5	Clear reporting structures allow new information to quickly and correctly travel to the necessary roles, including those that communicate directly with city council	2750	5500
235	15	Information Factor	Undefined reporting structure and responsibilities.	Scope changes are requested during construction as a result of political/public pressure	2	Combined	A, B, C	A7, B4, C5	Clear reporting structures allow new information to quickly and correctly travel to the necessary roles, including those that communicate directly with city council	3410	6820
236	15	Information Factor	Undefined reporting structure and responsibilities.	System element does not meet project vision	3		A	A8	Reporting structures and clear responsibilities are needed to catch inadequacies during design reviews	625	1875
237	15	Information Factor	Undefined reporting structure and responsibilities.	Poor model integration between traffic operations and LRT operations	4		A	A9	Clear reporting structure and responsibilities ensures the required communication between parties is maintained	385	1540
238	15	Information Factor	Undefined reporting structure and responsibilities.	Delayed City led utility work delays LRT contractor	1	Separated	A	A11		625	625
239	15	Information Factor	Undefined reporting structure and responsibilities.	Delayed City led utility work delays LRT contractor	1	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	2775
240	15	Information Factor	Undefined reporting structure and responsibilities.	Delayed City led utility work delays LRT contractor	1	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	3400
241	15	Information Factor	Undefined reporting structure and responsibilities.	Relationship between City and LRT contractor is not maintained	3		A	A12	Issues that arise from all levels/departments should be communicated back up to management, so that the overall city/contractor relationship is cared for	125	375
242	15	Information Factor	Undefined reporting structure and responsibilities.	Contractor delivers sub-par quality of general construction works	2	Separated	A	A20	Active project mamagement is required for initiating construction monitoring, inspection, and reporting of deficiencies	10000	20000
243	15	Information Factor	Undefined reporting structure and responsibilities.	Contractor delivers sub-par quality of general construction works	2	Separated	C	C10	Communication with contractor, City Council, public	1400	2800
244	15	Information Factor	Undefined reporting structure and responsibilities.	Contractor delivers sub-par quality of general construction works	2	Combined	A, C	A20, C10	Communication with contractor, City Council, public	11400	22800
245	16	Information Factor	Interfaces arise because of the application of the project development gating (or phases) system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	A	A7	This introduces repeated possibilities for scope to be changed, although is considered more beneficial than harmful	625	1875
246	16	Information Factor	Interfaces arise because of the application of the project development gating (or phases) system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	B	B4	This introduces repeated possibilities for scope to be changed, although is considered more beneficial than harmful	35	105
247	16	Information Factor	Interfaces arise because of the application of the project development gating (or phases) system.	Scope changes are requested during construction as a result of political/public pressure	3	Separated	C	C5	This introduces repeated possibilities for scope to be changed, although is considered more beneficial than harmful	2750	8250
248	16	Information Factor	Interfaces arise because of the application of the project development gating (or phases) system.	Scope changes are requested during construction as a result of political/public pressure	3	Combined	A, B, C	A7, B4, C5	This introduces repeated possibilities for scope to be changed, although is considered more beneficial than harmful	3410	10230
249	17	Information Factor	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access (on City-identified property)	4	Separated	A	A5	Timing for when to obtain access to lands must be scheduled according to planned/estimated construction progress. In other words, City's WBS must align and accomodate contractor's WBS.	125	500
250	17	Information Factor	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access (on City-identified property)	4	Separated	B	B1		35	140
251	17	Information Factor	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access (on City-identified property)	4	Separated	C	C3		625	2500
252	17	Information Factor	Insufficient and lack of alignment among Work Breakdown Structure (WBS), Contracting Work Breakdown Structure (CWBS), Cost Breakdown Structure (CBS), and Organization Breakdown Structure (OBS).	Delayed land access (on City-identified property)	4	Combined	A, B, C	A5, B1, C3		785	3140
253	18	Management Factor	Imprecise project cost estimate.	Land expropriation settlement costs exceed initial estimate	2	Separated	A	A4		1375	2750
254	18	Management Factor	Imprecise project cost estimate.	Land expropriation settlement costs exceed initial estimate	2	Separated	B	B1		35	70
255	18	Management Factor	Imprecise project cost estimate.	Land expropriation settlement costs exceed initial estimate	2	Separated	B	B2		750	1500
256	18	Management Factor	Imprecise project cost estimate.	Land expropriation settlement costs exceed initial estimate	2	Combined	A, B	A4, B1, B2		2160	4320
257	18	Management Factor	Imprecise project cost estimate.	Fill material is not readily available	3		B	B6	Cost estimate highly dependent on material availability	1250	3750
258	18	Management Factor	Imprecise project cost estimate.	Noise levels of LRT exceed noise allowances for residents, so noise walls must be added to the scope of work	2		B	B8	Cost estimate must account for inclusion of noise walls if required	50	100

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
259	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	LRV design/supply delays Service Commencement	2	Separated	A	A19	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	2750	5500
260	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	LRV design/supply delays Service Commencement	2	Separated	C	C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	3285	6570
261	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	LRV design/supply delays Service Commencement	2	Combined	A, C	A19, C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	6035	12070
262	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	Contractor delivers sub-par quality of general construction works	4	Separated	A	A20	Active project mamagement is required for initiating construction monitoring, inspection, and reporting of deficiencies	10000	40000
263	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	Contractor delivers sub-par quality of general construction works	4	Separated	C	C10	Communication with contractor, City Council, public	1400	5600
264	19	Management Factor	Discrepancies between the owners' expectations regarding project construction schedule, cost and quality.	Contractor delivers sub-par quality of general construction works	4	Combined	A, C	A20, C10	Communication with contractor, City Council, public	11400	45600
265	20	Management Factor	Lack of personal experience of the project teams.	City diverges from submittal review procedure leading to a claim from the contractor	3		A	A3	If the significance of this risk is not fully realized, it becomes increasingly more likely	1400	4200
266	20	Management Factor	Lack of personal experience of the project teams.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	A	A31	Experienced teams understand how certain actions could lead to risk take back	625	1250
267	20	Management Factor	Lack of personal experience of the project teams.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	C	C23, C33	Experienced teams understand how certain actions could lead to risk take back	1010	2020
268	20	Management Factor	Lack of personal experience of the project teams.	Risk transferred back to City due to construed City involvement outside contract	2	Combined	A, C	A31, C23, C33	Experienced teams understand how certain actions could lead to risk take back	1635	3270
269	20	Management Factor	Lack of personal experience of the project teams.	System element does not meet project vision	1		A	A8	Personal experience helps with catching inadequacies during design reviews	625	625
270	20	Management Factor	Lack of personal experience of the project teams.	Delayed City led utility work delays LRT contractor	1	Separated	A	A11		625	625
271	20	Management Factor	Lack of personal experience of the project teams.	Delayed City led utility work delays LRT contractor	1	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	2775
272	20	Management Factor	Lack of personal experience of the project teams.	Delayed City led utility work delays LRT contractor	1	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	3400
273	20	Management Factor	Lack of personal experience of the project teams.	Relationship between City and LRT contractor is not maintained	1		A	A12		125	125
274	20	Management Factor	Lack of personal experience of the project teams.	Inadequate systems and/or operations input into the design and construction	2		A	A22	Lack of personal experience leads to oversights, where involvement of systems/operations teams would fill gaps	8250	16500
275	20	Management Factor	Lack of personal experience of the project teams.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	2		B	B12	Experienced team memebers are critical for successfully navigating procurement and attracting proponents	10000	20000
276	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Scope changes are requested during construction as a result of political/public pressure	4	Separated	A	A7	LRT systems are heavily scutinized by the public, so are more likely to have elements of scope change	625	2500
277	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Scope changes are requested during construction as a result of political/public pressure	4	Separated	B	B4	LRT systems are heavily scutinized by the public, so are more likely to have elements of scope change	35	140
278	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Scope changes are requested during construction as a result of political/public pressure	4	Separated	C	C5	LRT systems are heavily scutinized by the public, so are more likely to have elements of scope change	2750	11000
279	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Scope changes are requested during construction as a result of political/public pressure	4	Combined	A, B, C	A7, B4, C5	LRT systems are heavily scutinized by the public, so are more likely to have elements of scope change	3410	13640
280	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	Poor model integration between traffic operations and LRT operations	1		A	A9		385	385
281	21	Management Factor	Incapability to predict and resolve project's problems related to new technological techniques and materials.	LRV Supplier faces Quality Issues during Testing and Commissioning	1		C	C19	Mostly LRV supplier's responsibility to anticipate problems. although City could potentially help mitigate problems if better prepared	385	385
282	22	Technical and Site Issues Factor	Contractor's unfamiliarity with the environmental circumstances and local weather.	Sloped ground collapsing due to natural cause or LRT/third party construction	3		A	A30	Environmental and geotechnical circumstances, e.g. rainfall periods, and presence of clay	385	1155
283	22	Technical and Site Issues Factor	Contractor's unfamiliarity with the environmental circumstances and local weather.	LRV design/supply delays Service Commencement	2	Separated	A	A19	LRV's must withstand conditions where they will be operated, or else rework may be required	2750	5500
284	22	Technical and Site Issues Factor	Contractor's unfamiliarity with the environmental circumstances and local weather.	LRV design/supply delays Service Commencement	2	Separated	C	C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	3285	6570
285	22	Technical and Site Issues Factor	Contractor's unfamiliarity with the environmental circumstances and local weather.	LRV design/supply delays Service Commencement	2	Combined	A, C	A19, C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	6035	12070

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
286	22	Technical and Site Issues Factor	Contractor's unfamiliarity with the environmental circumstances and local weather.	LRV Supplier faces Quality Issues during Testing and Commissioning	1		C	C19	Mostly LRV supplier's responsibility to anticipate problems. although City could potentially help mitigate problems if better prepared	385	385
287	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	7000
288	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	125
289	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	7125
290	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Separated	A	A27, A40, A41, A43, A43	Foreseeing the unkown is impossible, although special attention should be applied to potential defects	6500	6500
291	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Separated	C	C21, C32	Foreseeing the unkown is impossible, although special attention should be applied to potential defects	1010	1010
292	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	1	Combined	A, C	C21, C32, A27, A40, A41, A43	Foreseeing the unkown is impossible, although special attention should be applied to potential defects	7510	7510
293	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Unexpected additional drainage requirements	1		A	A6	Understanding of site circumstances, such as exisiting drainaige tie-in points would help mitigate conflicts	625	625
294	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Sloped ground collapsing due to natural cause or LRT/third party construction	3		A	A30	Site circumstances, such as slope history, adjacent existing structures, and nearby construction	385	1155
295	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Unexpected geotechnical conditions encountered, increasing construction costs	5		B	B14	Project site issues related to geotechnical issues	1250	6250
296	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Proposed alignment must change to accomodate existing utility, or utility has to be relocated	1		B	B7	Risk allowance carried at early stage of project (concept and prelim design) due to limited knowledge about site cercumstances	11212	11212
297	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Where private land is required although not realistically possible to expropriate, additional mitigation measures would be required to minimize impact, or costly redesign to avoid any/all interuption	1		B	B16	The capacity to develop unique solutions depends in part on knowledge of site circumstances	3000	3000
298	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Additional land requirments	2		C	C22		750	1500
299	23	Technical and Site Issues Factor	Lack of knowledge about site circumstances by the project team members.	Changes to LRT contract leading to knock-on effects	3		C	C20		1375	4125
300	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	21000
301	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	375
302	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	21375
303	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Separated	A	A2, A44	Because of the importance of such an interface, the LRT contractor tends to be well aware of how to mitigate conflicts as it is in their own interest	2750	8250
304	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	8850
305	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	17100
306	24	Bidding and Contracting Factor	Increase project interfaces conflicts when different contractors insist on their points of view.	Important construction schedule milestone deadlines are missed	3		A	A21	Third parties or LRT contractor insisting on their claims of being delayed by means outside of their control	3750	11250
307	25	Management Factor	Lack of trust among different project parties.	Insufficient City resources or budget	1		A	A25, A36, A39	Lack of trust within the team, requiring additional resources to manage interaces and care for neglected responsibilities	1625	1625
308	25	Management Factor	Lack of trust among different project parties.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	3	Separated	A	A27, A40, A41, A43, A43	Contractors understandably attempt to take advantage of every situation, so latent defects are often used for claims and extension of time, and for covering up other delays.	6500	19500
309	25	Management Factor	Lack of trust among different project parties.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	3	Separated	C	C21, C32	Contractors understandably attempt to take advantage of every situation, so latent defects are often used for claims and extension of time, and for covering up other delays.	1010	3030

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
310	25	Management Factor	Lack of trust among different project parties.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	3	Combined	A, C	C21, C32, A27, A40, A41, A43	Contractors understandably attempt to take advantage of every situation, so latent defects are often used for claims and extension of time, and for covering up other delays.	7510	22530
311	25	Management Factor	Lack of trust among different project parties.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	A	A31	Lack of trust that the prime contractor is capable of handling situations at hand can lead to City stepping in where it shouldn't in the first place	625	2500
312	25	Management Factor	Lack of trust among different project parties.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	C	C23, C33	Lack of trust that the prime contractor is capable of handling situations at hand can lead to City stepping in where it shouldn't in the first place	1010	4040
313	25	Management Factor	Lack of trust among different project parties.	Risk transferred back to City due to construed City involvement outside contract	4	Combined	A, C	A31, C23, C33	Lack of trust that the prime contractor is capable of handling situations at hand can lead to City stepping in where it shouldn't in the first place	1635	6540
314	25	Management Factor	Lack of trust among different project parties.	Relationship between City and LRT contractor is not maintained	5		A	A12	Trust must be established in order to maintain a healthy relationship	125	625
315	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	21000
316	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	375
317	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Interfaces with other construction projects lead to schedule dependencies and delay claims	3	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	21375
318	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	4	Separated	A	A27, A41, A43, A43	Although implicit and unavoidable, efforts to mitigate impact should be made in the contract preparation	7250	29000
319	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	4	Separated	C	C21, C32	Although implicit and unavoidable, efforts to mitigate impact should be made in the contract preparation	1010	4040
320	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	4	Combined	A, C	C21, C32, A27, , A41, A43, A43	Although implicit and unavoidable, efforts to mitigate impact should be made in the contract preparation	8260	33040
321	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	Unexpected additional drainage requirements	1		A	A6		625	625
322	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	City guidelines/specs for LRT infrastructure contractor contain errors or omissions	4		A	A32		175	700
323	26	Technical and Site Issues Factor	Insufficient and inaccurate work drawings and specifications.	City guidelines/specs for LRV Supplier contain errors or omissions	4		C	C24		1375	5500
324	27	Information Factor	No proper work packaging design and subcontracting.				A				0
325	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	A	A27, A40, A41, A43, A43	This IM problem exacerbates the effects that come out from encountered latent defects	6500	13000
326	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Separated	C	C21, C32	This IM problem exacerbates the effects that come out from encountered latent defects	1010	2020
327	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	2	Combined	A, C	C21, C32, A27, A40, A41, A43	This IM problem exacerbates the effects that come out from encountered latent defects	7510	15020
328	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Combined	A, B, C	A33, B18, C25	Environmental, construction, operations approvals	6470	25880
329	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	A	A33	Environmental, construction, operations approvals	35	140
330	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	B	B18	Environmental, construction, operations approvals	6385	25540
331	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	C	C25	Environmental, construction, operations approvals	50	200
332	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	Important construction schedule milestone deadlines are missed	2		A	A21	Third parties or LRT contractor insisting on their claims of being delayed by means outside of their control	3750	7500
333	28	Management Factor	Slow in change orders, permits and shop drawings submission and approval.	City diverges from submittal review procedure leading to a claim from the contractor	5		A	A3		1400	7000
334	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Insufficient City resources or budget	2		A	A25, A36, A39	A poorly written contract leads to a more time/energy/cost demanding project	1625	3250
335	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	14000
336	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	250

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
337	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	14250
338	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Separated	A	A27, A41, A43, A43	How latent defects are dealt with during construction depend on how the contract is written	5000	25000
339	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Separated	C	C21, C32	How latent defects are dealt with during construction depend on how the contract is written	1010	5050
340	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Combined	A, C	C21, C32, A27, A40, A41, A43	How latent defects are dealt with during construction depend on how the contract is written	6010	30050
341	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Separated	A	A2, A44	Potential to mitigate disputes	2750	8250
342	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	8850
343	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	3	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	17100
344	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Unidentified underground infrastructure conflicts	3		A	A28	The contract will determine how the impacts from unidentified infrastructure will be realized. For the most part, this risk is accepted and budgeted for.	2750	8250
345	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	A	A31	Ambiguities in the contract leave room for contractor to makes claims	625	1250
346	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Risk transferred back to City due to construed City involvement outside contract	2	Separated	C	C23, C33	Ambiguities in the contract leave room for contractor to makes claims	1010	2020
347	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Risk transferred back to City due to construed City involvement outside contract	2	Combined	A, C	A31, C23, C33	Ambiguities in the contract leave room for contractor to makes claims	1635	3270
348	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Unexpected additional drainage requirements	1		A	A6	Clear procedures for handling unexpected additional drainage work will mitigate this risk	625	625
349	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	A	A7	Unforseeable scope changes resulting from external requests are usually not covered by the project's budget, although further claims can be made due to subsequent impacts, which a poorly written contract can leave room for.	625	625
350	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	B	B4	Unforseeable scope changes resulting from external requests are usually not covered by the project's budget, although further claims can be made due to subsequent impacts, which a poorly written contract can leave room for.	35	35
351	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	C	C5	Unforseeable scope changes resulting from external requests are usually not covered by the project's budget, although further claims can be made due to subsequent impacts, which a poorly written contract can leave room for.	2750	2750
352	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Scope changes are requested during construction as a result of political/public pressure	1	Combined	A, B, C	A7, B4, C5	Unforseeable scope changes resulting from external requests are usually not covered by the project's budget, although further claims can be made due to subsequent impacts, which a poorly written contract can leave room for.	3410	3410
353	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	System element does not meet project vision	2		A	A8	Clarity and specificity in contract can aleviate the risk of undesired system elements	625	1250
354	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Sloped ground collapsing due to natural cause or LRT/third party construction	2		A	A30	Contract requirements place onus on contractor	385	770
355	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Paleontological resources are encountered	2	Separated	A	A34	Main means for ensuring LRT contractor follows government/environmental policies, and has appropriate resources for tackling this risk as/if is comes up	35	70
356	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Paleontological resources are encountered	2	Separated	C	C26, C34	Main means for ensuring LRT contractor follows government/environmental policies, and has appropriate resources for tackling this risk as/if is comes up	210	420
357	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Paleontological resources are encountered	2	Combined	A, C	A34, C26, C34	Main means for ensuring LRT contractor follows government/environmental policies, and has appropriate resources for tackling this risk as/if is comes up	245	490
358	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contract errors or omissions leave city vulnerable when disputing claims	5	Separated	A	A35		625	3125
359	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contract errors or omissions leave city vulnerable when disputing claims	5	Separated	C	C27		8250	41250
360	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contract errors or omissions leave city vulnerable when disputing claims	5	Combined	A, C	A35, C27		8875	44375

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
361	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Trackwork stray current requires city involvment to mitigate/repair damages	2		A	A10	Contract must dictate how to manage stray current	125	250
362	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed City led utility work delays LRT contractor	2	Separated	A	A11	This issue tends to be well documented/described in the contract, although still stands as the first line of defence against future disputes	625	1250
363	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed City led utility work delays LRT contractor	2	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	5550
364	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed City led utility work delays LRT contractor	2	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	6800
365	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Relationship between City and LRT contractor is not maintained	3		A	A12	Ambiguities in the contract leave room for interpretation and conflict between parties	125	375
366	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Construction inconveniences lead to public opposition	3	Separated	A	A13	Public communication expectations from LRT contractor can mitigate public perception of construction disturbances	625	1875
367	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Construction inconveniences lead to public opposition	3	Separated	C	C7	Public communication expectations from LRT contractor can mitigate public perception of construction disturbances	2750	8250
368	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Construction inconveniences lead to public opposition	3	Combined	A, C	A13, C7	Public communication expectations from LRT contractor can mitigate public perception of construction disturbances	3375	10125
369	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	LRT contractor lacks transparency or adequate public service	2		A	A15	Contract can be written to clearly define expections from LRT contractor	1250	2500
370	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Public expectations are not met despite design/construction being compliant with contract	3	Separated	A	A17	Contract defines the roles and expecattions from all parties to manage such instances	1250	3750
371	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Public expectations are not met despite design/construction being compliant with contract	3	Separated	C	C8, C39, C37	Communications with public, LRT contractor	1440	4320
372	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Public expectations are not met despite design/construction being compliant with contract	3	Combined	A, C	A17, C8, C39, C37	Communications with public, LRT contractor	2690	8070
373	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Combined	A, B, C	A33, B18, C25	Contract determines permitted City involvement	6470	25880
374	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	A	A33	Contract determines permitted City involvement	35	140
375	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	B	B18	Contract determines permitted City involvement	6385	25540
376	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Delayed approvals/permits and/or additional efforts required to meet approval process from government agencies	4	Separated	C	C25	Contract determines permitted City involvement	50	200
377	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contractor delivers sub-par quality of general construction works	1	Separated	A	A20	Large potential to avoid insufficient quality of construction through contract	10000	10000
378	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contractor delivers sub-par quality of general construction works	1	Separated	C	C10	Communication with contractor, City Council, public	1400	1400
379	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contractor delivers sub-par quality of general construction works	1	Combined	A, C	A20, C10	Communication with contractor, City Council, public	11400	11400
380	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Inadequate systems and/or operations input into the design and construction	3		A	A22	Contract details specify how certain teams are involved	8250	24750
381	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contaminated ground is encountered, requiring ground remediation and disposal	2	Combined	A, B	A24, B5, C11, C31		15125	30250
382	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contaminated ground is encountered, requiring ground remediation and disposal	2	Separated	A	A24		13750	27500
383	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contaminated ground is encountered, requiring ground remediation and disposal	2	Separated	B	B5		625	1250
384	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Contaminated ground is encountered, requiring ground remediation and disposal	2	Separated	C	C11, C31		750	1500
385	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	3		B	B12	A well written contract will attract proponents	10000	30000
386	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Occurance of a pandemic	5		C	C28		385	1925
387	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Impacts from having to integrate with other LRT projects	1		C	C15	Cost impacts are usually accounted for in the contract, although schedule impacts are sometimes unavoidable	30000	30000
388	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Impacts on LRV contract from having to integrate with other LRT projects	1		C	C16	Cost impacts are usually accounted for in the contract, although schedule impacts are sometimes unavoidable	13750	13750
389	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Changes to LRT contract leading to knock-on effects	4		C	C20		1375	5500

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
390	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Failing to fulfill commitments to targeted group	2		C	C18	Depends on what the expectation is on the contractor	175	350
391	29	Bidding and Contracting Factor	Unclear contract details and badly written contract.	Force majeure or severe weather event	5		C	C29		200	1000
392	30	Management Factor	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	City diverges from submittal review procedure leading to a claim from the contractor	5		A	A3		1400	7000
393	30	Management Factor	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	Delayed City led utility work delays LRT contractor	2	Separated	A	A11	Inherent connection	625	1250
394	30	Management Factor	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	Delayed City led utility work delays LRT contractor	2	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	5550
395	30	Management Factor	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	Delayed City led utility work delays LRT contractor	2	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	6800
396	30	Management Factor	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	1		B	B12	Developing and executing a timely procurement and a complete schedule determines how successfully a project can be presented to proponents	10000	10000
397	32	Management Factor	Application of fast-track engineering and construction techniques.	City diverges from submittal review procedure leading to a claim from the contractor	4		A	A3		1400	5600
398	32	Management Factor	Application of fast-track engineering and construction techniques.	Inadequate systems and/or operations input into the design and construction	4		A	A22	Systems involvement can often be utilized after civil construction has already taken place	8250	33000
399	33	Bidding and Contracting Factor	Lack of solid contracting strategy vision at early stage of the project.				A				0
400	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Insufficient City resources or budget	2		A	A25, A36, A39		1625	3250
401	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	A	A31	Contracting strategy determines the expected level of involvement from the City	625	2500
402	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	C	C23, C33	Contracting strategy determines the expected level of involvement from the City	1010	4040
403	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Risk transferred back to City due to construed City involvement outside contract	4	Combined	A, C	A31, C23, C33	Contracting strategy determines the expected level of involvement from the City	1635	6540
404	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	System element does not meet project vision	2		A	A8	Contract type dictates degree of prescriptiveness	625	1250
405	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	City directs LRT contractor to rectify perceived deficiencies, which are ultimately deemed unnecessary in court	2		A	A26	Contract type dictates degree of city involvement	175	350
406	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Inadequate systems and/or operations input into the design and construction	2		A	A22	Dictates sequencing and level of involvement of particular parties	8250	16500
407	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Unexpected geotechnical conditions encountered, increasing construction costs	2		B	B14	Risk depends on who is best capable of investigating and monitoring this risk and who the risk is ultimately assigned to in the contract	1250	2500
408	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	2		B	B12	Type of contracting strategy would directly influence how appealing a project is seen by proponents	10000	20000
409	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	Contract changes to accomodate LRV operations and maintenance improvements	3		C	C17	Contract type could solve or create this problem	1250	3750
410	34	Bidding and Contracting Factor	Type of contracting strategy; EP, EPC, and EPCM.	LRV design/supply delays Service Commencement	4		C	C9, C30, C38, C41, C42	If the city takes on the contract for LRT procurement, they take on the risk for cost implications for delayed Service Commencement	3285	13140
411	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Insufficient City resources or budget	1		A	A25, A36, A39	Prepare all parties with realistic expectations so that resources can be allocated apropriately	1625	1625
412	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	7000
413	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	125
414	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Interfaces with other construction projects lead to schedule dependencies and delay claims	1	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	7125
415	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Separated	A	A2, A44	Enhances awareness of critical interfaces	2750	5500
416	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	5900
417	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	11400
418	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	A	A31	Interface issues should be identified as early as possible so that the City doesn't feel the need to step in later	625	2500

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
419	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Risk transferred back to City due to construed City involvement outside contract	4	Separated	C	C23, C33	Interface issues should be identified as early as possible so that the City doesn't feel the need to step in later	1010	4040
420	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Risk transferred back to City due to construed City involvement outside contract	4	Combined	A, C	A31, C23, C33	Interface issues should be identified as early as possible so that the City doesn't feel the need to step in later	1635	6540
421	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Delayed City led utility work delays LRT contractor	5	Separated	A	A11	Critical piece of information that must be conveyed	625	3125
422	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Delayed City led utility work delays LRT contractor	5	Separated	C	C6, C36	Communication with utility companies and LRT contractor	2775	13875
423	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Delayed City led utility work delays LRT contractor	5	Combined	A, C	A11, C6, C36	Communication with utility companies and LRT contractor	3400	17000
424	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	LRV design/supply delays Service Commencement	1	Separated	A	A19	LRV's must withstand conditions where they will be operated, or else rework may be required	2750	2750
425	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	LRV design/supply delays Service Commencement	1	Separated	C	C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	3285	3285
426	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	LRV design/supply delays Service Commencement	1	Combined	A, C	A19, C9, C30, C38, C41, C42	Insufficient quality of vehicles after they have been delivered has a potentially significant impact on schedule for the problem to be remedied	6035	6035
427	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Inadequate systems and/or operations input into the design and construction	1		A	A22	Opportunity to highlight importance of this interface	8250	8250
428	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Where private land is required although not realistically possible to expropriate, additional mitigation measures would be required to minimize impact, or costly redesign to avoid any/all interuption	2		B	B16	Early notice and emphasis on challenging interfaces improves likelihood of better management	3000	6000
429	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Risk of insufficient competitive tension if there aren't enough interested parties in bidding process	1		B	B12	Demonstrating a strong understanding of interface issues and communicating these fully to proponents gives proponents confidence they know what they're getting into	10000	10000
430	35	Bidding and Contracting Factor	Identification of interface issues in Invitation to Bid.	Failing to fulfill commitments to targeted group	2		C	C18	Depends on what the expectation is on the contractor	175	350
431	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Insufficient City resources or budget	1		A	A25, A36, A39	The better suited the contractor is to meet the priject goals, the less likely City resources will be tied up dealing with conflicts and additional work down the road	1625	1625
432	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	14000
433	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	250
434	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Interfaces with other construction projects lead to schedule dependencies and delay claims	2	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	14250
435	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Separated	A	A2, A44	Outcome of this risk depends primarily on the nature of the interuption and how the contract handles events, although selecting contractors that can better avoid conflicts is desirable	2750	5500
436	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	5900
437	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	2	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	11400
438	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Risk transferred back to City due to construed City involvement outside contract	1	Separated	A	A31	Appraisal of bids allows city to select a contractor most likely to handle their own, and not require additional/unnecessary city involvement	625	625
439	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Risk transferred back to City due to construed City involvement outside contract	1	Separated	C	C23, C33	Appraisal of bids allows city to select a contractor most likely to handle their own, and not require additional/unnecessary city involvement	1010	1010
440	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Risk transferred back to City due to construed City involvement outside contract	1	Combined	A, C	A31, C23, C33	Appraisal of bids allows city to select a contractor most likely to handle their own, and not require additional/unnecessary city involvement	1635	1635
441	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	System element does not meet project vision	2		A	A8	Bid appraisal allows the city to select the team that best understands their goals, and also to understand where further attention/focus is required moving into construction	625	1250
442	36	Bidding and Contracting Factor	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management.	Inadequate systems and/or operations input into the design and construction	1		A	A22	Opportunity to review a proponent's level of understanding and intentions	8250	8250
443	37	Technical and Site Issues Factor	Weather climate conditions problems.	Sloped ground collapsing due to natural cause or LRT/third party construction	2		A	A30		385	770
444	37	Technical and Site Issues Factor	Weather climate conditions problems.	City transfers snow/ice onto infrastructure during construction	5		A	A14	Communication with City departments	125	625

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
445	38	Other Interface Problems Factor	Unexpected changes in materials and labour availability and cost.	Fill material is not readily available	5		B	B6		1250	6250
446	39	Technical and Site Issues Factor	Geological circumstances problems.	Sloped ground collapsing due to natural cause or LRT/third party construction	2		A	A30		385	770
447	39	Technical and Site Issues Factor	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Combined	A, B	A24, B5	Ground contamination	15125	15125
448	39	Technical and Site Issues Factor	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	A	A24	Ground contamination	13750	13750
449	39	Technical and Site Issues Factor	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	B	B5	Ground contamination	625	625
450	39	Technical and Site Issues Factor	Geological circumstances problems.	Contaminated ground is encountered, requiring ground remediation and disposal	1	Separated	C	C11, C31	Communications with government environmental agencies, as well as internal and external monitors	750	750
451	39	Technical and Site Issues Factor	Geological circumstances problems.	Unexpected geotechnical conditions encountered, increasing construction costs	4		B	B14		1250	5000
452	40	Law and Regulation Factor	Unclear company standard operating procedures.	Insufficient City resources or budget	1		A	A25, A36, A39	Unclear company standard operating procedures lead to increased demand on resources due to lowered efficiency	1625	1625
453	41	Law and Regulation Factor	Inexperience with the government auditing protocols and procedures.	Insufficient City resources or budget	1		A	A25, A36, A39	Well trained and experienced employees work more efficiently and at an overal lower cost to the City	1625	1625
454	42	Law and Regulation Factor	Inexperience with local laws and other government regulations and modification in laws and regulations.	Insufficient City resources or budget	1		A	A25, A36, A39	Well trained and experienced employees work more efficiently and at an overal lower cost to the City	1625	1625
455	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Insufficient City resources or budget	1		A	A25, A36, A39	Well trained and experienced employees work more efficiently and at an overal lower cost to the City	1625	1625
456	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	A	A7	Lack of understanding of law and government regulations could lead to unexpected scope changes	625	625
457	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	B	B4	Lack of understanding of law and government regulations could lead to unexpected scope changes	35	35
458	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Scope changes are requested during construction as a result of political/public pressure	1	Separated	C	C5	Lack of understanding of law and government regulations could lead to unexpected scope changes	2750	2750
459	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Scope changes are requested during construction as a result of political/public pressure	1	Combined	A, B, C	A7, B4, C5	Lack of understanding of law and government regulations could lead to unexpected scope changes	3410	3410
460	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	4	Separated	B	B9	Understanding of current and potential regulations and laws	3750	15000
461	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	4	Separated	C	C13	Understanding of current and potential regulations and laws	385	1540
462	43	Law and Regulation Factor	Inexperience with building codes, by-laws, statutes and other government regulations.	Change of law introduces new costs, e.g. environmental regulations, railway regulations, etc	4	Combined	B, C	B9, C13	Understanding of current and potential regulations and laws	4135	16540
463	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	A	A1, A37, A38, A42	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7000	35000
464	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Separated	B	B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	125	625
465	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Interfaces with other construction projects lead to schedule dependencies and delay claims	5	Combined	A, B	A1, A37, A38, A42, B17	Depending on the magnitude of the both interfacing projects, delays and cost can be substantial.	7125	35625
466	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Separated	A	A27, A40, A41, A43, A43		6500	32500
467	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Separated	C	C21, C32		1010	5050
468	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Latent defects and/or incorrect as-builts leading to schedule and cost impacts to remedy	5	Combined	A, C	C21, C32, A27, A40, A41, A43		7510	37550
469	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Separated	A	A2, A44		2750	13750
470	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Separated	C	C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	2950	14750
471	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Major interfaces, such as utilities/rail/pipelines, cause extraordinary delay to LRT contractor	5	Combined	A, C	A2, A44, C2, C40, C35	City needs to define what is expected from both the contractor and the utility/rail/pipeline	5700	28500
472	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Sloped ground collapsing due to natural cause or LRT/third party construction	2		A	A30	Relevant for pre-desturbed ground, or ground that has been previously reinforced	385	770
473	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Damage to reputation if contractor causes damage to third party property	5		A	A29	Project Management is required to initiate construction site monitoring, as well as investigation post damage	385	1925
474	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Contaminated ground is encountered, requiring ground remediation and disposal	3	Combined	A, B	A24, B5	Ground contamination	15125	45375
475	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Contaminated ground is encountered, requiring ground remediation and disposal	3	Separated	A	A24	Ground contamination	13750	41250
476	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Contaminated ground is encountered, requiring ground remediation and disposal	3	Separated	B	B5	Ground contamination	625	1875

Appendix B: Raw Data - Interface Problem & Risk links

Link ID	Factor ID	Interface Factor	Interface Problem	LRT Risks	Weighting	Grouping	Project	Risk ID	Notes	Severity	Weighted Severity
477	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Contaminated ground is encountered, requiring ground remediation and disposal	3	Separated	C	C11, C31	Ground contamination	750	2250
478	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Proposed alignment must change to accomodate existing utility, or utility has to be relocated	3		B	B7		11212	33636
479	44	Other Interface Problems Factor	Project nature issues (brownfield vs greenfield)	Where private land is required although not realistically possible to expropriate, additional mitigation measures would be required to minimize impact, or costly redesign to avoid any/all interuption	3		B	B16		3000	9000
480	45	Bidding and Contracting Factor	Free issue items.				A				0
481	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Land expropriation settlement costs exceed initial estimate	2	Separated	A	A4	Once in construction, battery limits are much better defined and understood, making this less of a concern	1375	2750
482	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Land expropriation settlement costs exceed initial estimate	2	Separated	B	B1		35	70
483				Land expropriation settlement costs exceed initial estimate	2	Separated	B	B2		750	1500
484	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Land expropriation settlement costs exceed initial estimate	2	Combined	A, B	A4, B1, B2		2160	4320
485	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access (on City-identified property)	2	Separated	A	A5	Planning and scheduling for when lands are required, and what steps are required in order to acquire those lands	125	250
486	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access (on City-identified property)	2	Separated	B	B1		35	70
487	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access (on City-identified property)	2	Separated	C	C3		625	1250
488	46	Bidding and Contracting Factor	Insufficient definition of projects battery limits and tie-in information at early stage of the project.	Delayed land access (on City-identified property)	2	Combined	A, B, C	A4, B1, C3		785	1570
489	47	Bidding and Contracting Factor	Unclear system completion requirements.	Inadequate systems and/or operations input into the design and construction	1		A	A22	The system'/operations teams would provide this insight	8250	8250