UNIVERSITÉ DE MONTRÉAL

ANALYZING MANAGEMENT PROCESSES WITHIN A DISTRIBUTED TEAM CONTEXT : THE CASE OF A CANADA-CHINA CONSTRUCTION PROJECT

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ANALYZING MANAGEMENT PROCESSES WITHIN A DISTRIBUTED TEAM CONTEXT : THE CASE OF A CANADA-CHINA CONSTRUCTION PROJECT

présenté par: SU Chen

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RÉSUMÉ

Dans un contexte d'équipe distribuée (aussi appelée équipe dispersée), le cheminement approprié et efficace de l'information entre les membres d'une équipe est essentiel au succès de la mise en œuvre d'un projet et à sa réussite. Il importe de mieux comprendre le cheminement de l'information au cours de projets de construction, afin de repérer diverses lacunes et d'établir des solutions appropriées, de façon à améliorer encore davantage les processus de gestion dans ce genre de projet. Malheureusement, les études portant sur les processus de gestion à partir de l'observation du cheminement de l'information dans le cadre de projets de construction, et particulièrement dans le cadre de projets internationaux réalisés dans un environnement de travail distribué, sont très rares.

La présente étude vise à examiner en profondeur les processus de gestion dans le cadre d'un cas réel et à analyser systématiquement les courriers électroniques échangés entre les membres de la direction d'un projet de construction international. Nous décrivons d'abord les structures relatives au cheminement de l'information observées dans le cadre du projet de construction en question, et ce, à la lumière de l'analyse des courriers électroniques. Compte tenu du volume du flux de l'information s'y rapportant, nous avançons ensuite que la gestion des communications, de l'intégration, des approvisionnements, de la gestion du matériel et de la gestion des ressources humaines (RH) constituent les principaux enjeux de ce contexte de travail distribué.

L'examen rigoureux de l'interaction et des communications observées dans les groupes de messages révèle par ailleurs que la gestion de l'intégration, des approvisionnements et du matériel sont les enjeux les plus cruciaux en ce qui a trait à la réalisation du projet dans ce contexte distribué. Les différents problèmes, notamment liés à l'intégration, aux approvisionnements et matériel, ainsi que les problèmes plus courants, sont identifiés et bien définis dans le cadre de ce travail. Une série de modèles génériques, de modèles de cas d'utilisation et de processus proposés dans le présent rapport fournissent finalement des solutions efficaces aux problèmes courants ainsi qu'aux différents problèmes liés à la gestion de l'intégration, des approvisionnements et du matériel.

Mots-clés :
Équipe distribuée, flux d'information, secteur de la construction, processus de gestion de projet, communication.

ABSTRACT

In a distributed team context, appropriate and effective information flows among team participants are vital to the success of the project's implementation and performance. An understanding of information flows during construction is also essential to identify various issues and find the appropriate solutions to address them in order to further improve construction processes. However, the research analyzing management processes by observing information flows in the construction industry, especially in projects executed in an internationally distributed work environment, is quite limited.

This study closely observes the business processes of a real case, and systematically analyzes the email messages exchanged at the management level of this international construction project. First, the information flow patterns associated with the construction project are identified on the basis of a study of the email messages. Based on the volume of information flows, communication, integration, procurement, materials and HR are found to be the most important areas involved in this distributed team context.

The in-depth observation of the interactive and communicative features of the exchanged message groups reveals that integration, procurement and materials are the most critical processes to project execution in this distributed work environment. The various issues associated with integration, procurement and materials, and the common problems, are identified and documented. A series of generic models, use case models, and activity diagram models proposed in this report provide an effective solution to address various issues and solve common problems associated with integration, procurement and materials management.

Keywords:
Distributed Team, Information Flows, Construction Industry, Project Management Process, Communication

CONDENSÉ EN FRANÇAIS

INTRODUCTION

Réaliser un projet de construction est une tâche complexe; les organisations en charge de tels projets doivent relever des défis encore plus grands lorsqu'il s'agit d'un projet international. Quels sont les problèmes et les difficultés qu'ont à traiter et à surmonter les participants à un projet de construction d'envergure internationale réel? Quelles sont la structure et les caractéristiques du cheminement de l'information dans un contexte dispersé? Comment pouvons-nous identifier les problèmes et les difficultés liés à cette situation? Quelles solutions peuvent être proposées afin d'aider les participants à un projet de construction à remédier à ces problèmes et à améliorer leurs processus de gestion? Ce sont toutes des questions qui sous-tendent la présente étude.

La présente étude vise à analyser les processus de gestion d'un projet de construction réalisé dans un contexte collaboratif et distribué, à définir les problèmes soulevés par certains processus précis relatifs au cheminement de l'information et à proposer des solutions à ces problèmes. Plus précisément, elle a pour but de: (1) définir les structures relatives au cheminement de l'information dans le cadre d'un projet de construction international réalisé dans un contexte distribué; (2) analyser les principaux processus concernés et définir les problèmes s'y rattachant; (3) proposer des solutions appropriées visant à remédier à ces problèmes et à accroître l'efficacité des processus de gestion de projet.

D'une manière générale, le fait qu'il s'agisse d'un projet *de construction* d'envergure *internationale* dans un contexte *distribué* est au cœur de la présente étude. Plus particulièrement, cette étude analyse les courriers électroniques échangés entre le gestionnaire du projet de construction présent sur le terrain et les autres membres de l'équipe distribuée répartis partout dans le monde.

L'étude de cas dont il est question dans le présent rapport concerne un projet de moyenne envergure réalisé en Chine et dirigé par un fournisseur canadien. La période d'observation a débuté en janvier 2005 et s'est terminée en décembre 2005, date à laquelle la dernière étape du projet de construction a été menée à terme.

REVUE DE LITTÉRATURE

L'examen des études publiées antérieurement vise à mieux comprendre les travaux de recherche réalisés par différents chercheurs dans des domaines pertinents et, surtout, à en identifier les lacunes. Dans le cas qui nous préoccupe, l'examen des études pertinentes a mis l'accent sur le cheminement de l'information dans le cadre d'un projet de construction distribué ainsi que sur la réingénierie et la modélisation des processus de gestion connexes.

Le cheminement de l'information est déterminant quant au succès d'un projet de construction. Il est important pour les chercheurs d'observer et de définir les problèmes liés au cheminement de l'information dans le cadre d'un projet de construction réel, afin de proposer des solutions appropriées, de sorte que l'on puisse remédier à ces problèmes à l'avenir et mener à terme de tels projets. Toutefois, les données et les conclusions existantes tirées de l'observation d'un cas réel sont assez limitées. En fait, les études portant sur les structures du cheminement de l'information et les problèmes qui y sont liés dans le cadre d'un projet de construction décentralisé, notamment lorsque les équipes travaillent de façon asynchrone, sont très rares.

En outre, l'élaboration et la mise en application d'un modèle de gestion en ce qui a trait à la collaboration et à la communication dans le cadre d'un projet de construction totalement asynchrone et très étendu sur le plan géographique sont peu documentées. L'établissement d'une structure relative au cheminement de l'information dans le cadre d'un projet de construction dont le contexte est décentralisé apportera une contribution énorme aux nombreux comptes rendus de recherche. L'identification de divers problèmes liés au cheminement de l'information et l'établissement de nouveaux modèles y remédiant faciliteront la tâche des membres d'une équipe décentralisée en ce qui a trait à la visualisation et à l'amélioration des processus de gestion de projet. Ces problèmes constituent précisément l'objet du présent rapport, et les méthodologies de recherche décrites ci-après ont été utilisées afin de les examiner.

MÉTHODOLOGIES DE RECHERCHE

Afin d'étudier le projet ciblé pour la recherche, des données provenant de deux sources principales furent utilisées: (i) les archives contenant tous les courriers électroniques échangés entre les acteurs du projet au cours de 2005 fournies par la société concernée, soit 3650 courriers électroniques; (ii) des entretiens avec les principaux acteurs du projet. Au total, 20 entretiens ont eu lieu entre les gestionnaires de la société et d'autres intervenants. Ces entretiens nous ont permis de mieux comprendre divers volets de la réalisation du projet de construction concerné et sont venus compléter la principale source de données (les courriers électroniques), en fournissant un aperçu plus global du projet.

Le processus de recherche a comporté sept (7) étapes. La première étape a consisté à diviser les courriers électroniques en deux catégories. L'une des catégories contenait les messages relatifs au contexte local où le site du projet était situé, alors que l'autre catégorie regroupait les messages relatifs au contexte distribué. La deuxième étape consistait à revoir tous les messages, de façon à observer le cheminement de l'information dans un contexte distribué. Lors de la troisième étape, tous les messages ont été classés selon les catégories établies dans le PMBOK® par le Project Management Institute (2004). La quatrième a été de repérer tous les messages portant sur les processus de construction majeurs. Lors de la cinquième étape, le contenu de ces messages a été examiné, et les problèmes liés aux processus qui y étaient décrits ont été définis. La sixième étape consistait à établir les besoins pour de nouveaux processus, en fonction des problèmes signalés et à la lumière de l'observation du cas ainsi que de l'examen général effectué. Finalement, la septième étape a consisté à proposer de nouveaux processus, en utilisant le formalisme UML (*Unified Modeling Language*), tout en tenant compte des modèles existants.

Pour analyser systématiquement le cheminement de l'information, nous avons divisé les dossiers de communication en 1865 groupes de messages. Les éléments contenus dans la nouvelle banque de données comprenaient le numéro de série du groupe de messages, la date de création du groupe de messages, le sujet des messages échangés, la valeur communicationnelle et informative, la catégorie du processus de gestion de projet, la catégorie du but de la communication, le nom du destinateur et du destinataire de chacun des messages, les objectifs de la communication, les boucles de rétroaction et la durée de la communication. Afin d'améliorer la gestion de projet dans le cas qui nous préoccupe, le formalisme UML a été utilisé comme outil de modélisation pour définir et décrire les principaux processus de gestion dans le cadre d'un projet de construction.

RÉSULTATS ET SOLUTIONS PROPOSÉES

Les chapitres 4 et 5 présentent les résultats et les solutions proposées à la lumière de l'examen approfondi et de l'observation rigoureuse du cheminement de l'information entre les intervenants d'un projet dans un contexte distribué. Le chapitre 4 est divisé en trois parties. La première partie décrit le cas observé. La deuxième partie définit et établit la structure du cheminement de l'information dans un contexte décentralisé. Enfin, la troisième partie présente et analyse les principaux processus de gestion dans le cadre d'un projet de construction. Le chapitre 5, quant à lui, propose des solutions aux problèmes soulevés.

Description du cas

Le présent cas vise une société canadienne qui élabore et met en œuvre des projets clés en main partout dans le monde. Le projet dont il est question ici prévoit la construction de bâtiments de services, de serres, de l'équipement, du système de production et des installations connexes, et a lieu dans le nord de la Chine. Durant la réalisation du projet, la majorité des gestionnaires (directeur général, directeur de projet et d'autres responsables des services fonctionnels) sont localisés au Canada. L'équipe sur le terrain, en Chine, était formée du directeur des travaux et de sept (7) ingénieurs (superviseurs techniques) provenant du Canada. Le personnel embauché sur place était composée de huit employés, lesquels, dans les bureaux en Chine, assumaient principalement des tâches administratives nécessaires à la réalisation du projet et offraient des services au personnel basé au Canada. Vingt travailleurs (monteurs) ont été embauchés directement par l'équipe sur le terrain et rendaient compte au directeur des travaux. L'entrepreneur principal a affecté environ 50 employés aux travaux de génie civil et de bétonnage. Différents sous-contractants ont été embauchés, afin de fournir des services d'impartition spécialisés nécessaires à la réalisation du projet. Des fournisseurs locaux ont assuré les approvisionnements du matériel requis.

Dans le cadre de ce contexte de collaboration distribuée entre le bureau de gestion de projet international (BGPI) et le bureau central (BC), la communication s'est principalement faite par ordinateur, notamment par l'intermédiaire de courriers électroniques. Le choix et l'utilisation de ce moyen de communication ont été commentés lors des entretiens de rétroaction des participants au projet. La disponibilité de pratiquement un seul moyen de communication a soulevé des difficultés en ce qui a trait au cheminement de l'information entre les membres de l'équipe décentralisée. Par ailleurs, les courriers électroniques archivés se sont avérés une occasion unique d'accéder à l'ensemble des données et des sources d'information dans le cadre de la présente étude et observation.

Structure du cheminement de l'information dans un contexte décentralisé

L'une des observations les plus importantes réside dans la répartition du volume des messages selon les principaux enjeux du projet, répartition effectuée en fonction du contenu des messages. Les plus importants enjeux établis selon le flux de l'information s'y rapportant sont la communication, l'intégration, les approvisionnements, le matériel et les RH. La répartition du volume des messages portant sur la communication, l'intégration, les approvisionnements, le matériel et les RH s'établit comme suit : 41,4 %, 20,1 %, 8,7 %, 8,6 % et 6,4 %, respectivement. Contrairement aux autres chercheurs, nous avons conclu que la communication est le principal enjeu en termes de répartition du volume des messages. Dans la lignée d'autres travaux de recherche, nous avons effectué une analyse détaillée du contenu des groupes de messages selon les différents enjeux, puis nous avons tenté de récréer les processus de gestion de projet s'y rattachant.

En ce qui concerne l'enjeu de la communication, la diffusion de l'information, la gestion des intervenants et la présentation de l'information sur le rendement représentent 80 %, 15 % et 5 %, respectivement, des groupes de messages échangés. La diffusion de l'information est certainement le principal objectif du cheminement de l'information au sein du processus de communication. Dans le contexte de la gestion de projet, l'intégration consiste principalement en l'intégration efficace des processus nécessaires à la réalisation du projet, et ce, conformément aux procédures établies par l'organisation concernée. Dans le cas qui nous préoccupe, en premier lieu, le système intégré de contrôle du changement a été abordé dans 48 % de l'ensemble des groupes de messages liés à l'intégration. La surveillance et le contrôle des travaux se placent au deuxième rang, représentant 24 %. Comme la phase de construction observée comprenait la dernière étape du projet, le volume du flux de l'information portant sur l'achèvement du projet figure au troisième rang, ayant été abordé dans 18 % de l'ensemble des groupes de messages liés à l'intégration. En dernier lieu, on retrouve la réalisation des travaux, qui ne représentent que 10 %.

La gestion des approvisionnements est un processus complexe. Étant donné le contexte international du projet de construction concerné, les principaux sujets liés aux approvisionnements dont il était question dans les messages échangés visaient les achats locaux ou les bons de commande locaux effectués par le BGPI. Les trois sujets les plus récurrents relativement à cet enjeu portaient sur la réponse d'un vendeur (33 %), le choix d'un vendeur (29 %) et l'administration d'un contrat (16 %). La planification des achats et des contrats représentaient 11 % et 9 %, respectivement. En outre, le matériel (matériaux, outillage, etc.) est essentiel à la réalisation efficace d'un projet de construction, surtout dans un contexte international. Nous avons regroupé les groupes de messages liés au matériel et pu établir les catégories des processus de gestion du matériel requis dans la cadre de ce projet. Les processus liés à la gestion du matériel dans le cas qui nous préoccupe sont la planification, l'acquisition, l'entreposage, la livraison, la vérification et le contrôle. Nos observations nous ont permis d'établir la répartition du volume des messages selon chacun des processus de gestion du matériel et d'en indiquer l'importance. Ces renseignements peuvent servir à recréer la structure du cheminement de l'information, ce qui serait utile aux professionnels responsables de mettre en œuvre des projets dans un contexte similaire. Plus important encore, ces observations témoignent de l'existence et de la nécessité de chacun des processus de gestion du matériel dans le cadre d'un projet de construction.

Les résultats de cette analyse permettront de mieux comprendre à l'avenir les processus de gestion réels et faciliteront l'élaboration de nouveaux processus dans le cadre du projet de construction en cause. Les conclusions présentées dans le présent rapport suggèrent fortement que les prochaines études dans ce domaine consacrent leurs efforts à l'analyse plus approfondie des principaux enjeux dont il est question aux présentes. En outre, nos observations révèlent que le cheminement interne de l'information dans le cadre d'un projet réalisé dans un contexte distribué joue un rôle majeur. Le gestionnaire de projet basé au BGPI a fait parvenir au directeur de projet basé au BC plus de 60 % de tous les courriers électroniques qu'il a envoyés et, au directeur général, 28 % de tous les courriers électroniques qu'il a envoyés. Le volume du cheminement interne de l'information représente environ 95 % de l'ensemble des groupes de messages échangés. Seuls 5 % des groupes de messages ont été envoyés à des intervenants externes. En outre, de telles observations témoignent du fait que les courriers électroniques archivés constituent une bonne source d'information à l'occasion d'études visant à identifier des problèmes liés aux processus de gestion interne dans un contexte décentralisé et à proposer des solutions appropriées.

Identification et analyse des principaux processus de construction

Les études menées antérieurement se sont principalement penchées sur la structure du cheminement de l'information, en mesurant la répartition du volume selon différents enjeux et divers processus de gestion de projet. La répartition du volume lié à un processus de gestion peut permettre d'établir la mesure dans laquelle l'équipe du BGPI dépend du BC en ce qui a trait à la diffusion de l'information dans ce contexte décentralisé, afin de s'assurer que les travaux connexes soient effectués. Toutefois, ce genre d'observation ne permet pas de définir de façon précise la nature du sujet véhiculé par le message. Lorsque nous avons établi l'objectif de chacun des groupes de messages pour l'ensemble des courriers électroniques archivés, nous avons conclu que tous les messages pouvaient être classés en deux grandes catégories, soit les demandes de renseignements et le partage de l'information. Les demandes de renseignements comprennent les directives, les demandes et les rapports spéciaux. Le partage de l'information consiste en la remise d'avis et la communication de routine.

Les messages concernant des avis et la communication de routine se produisent généralement lorsqu'une tâche est terminée, alors que ceux qui transmettent des directives, des demandes et des rapports spéciaux sont envoyés tout long de la durée du projet. Le volet le plus interactif du cheminement de l'information dans la catégorie des demandes de renseignements, notamment entre le gestionnaire de projet basé au BGPI et les autres intervenants basés au BC, est de par sa nature plus susceptible de couvrir des sujets variés. Par ailleurs, nous avons organisé la répartition des groupes de messages en différentes sous-catégories. La communication de routine représente 37 % de l'ensemble des groupes de messages, elle occupe ainsi le premier rang des cinq sous-catégories. La deuxième sous-catégorie, représentant 32 % de l'ensemble des groupes de messages, est constituée des rapports spéciaux. Les demandes de toutes sortes forment la troisième plus importante sous-catégorie, soit 16 % de l'ensemble des groupes de messages. Enfin, les directives et les avis représentent, respectivement, 7 % et 8 % de l'ensemble des groupes de messages.

Les groupes de messages liés au partage de l'information ne soulèvent généralement aucune difficulté d'ordre fonctionnel. Comparativement à cette catégorie, les courriers électroniques classés dans les sous-catégories des directives, des demandes et des rapports spéciaux traitent davantage de différentes questions et de différents problèmes. Nous avons par ailleurs pu observer que la répartition du volume des messages effectue des boucles de rétroaction entre les destinateurs et les destinataires. Les sujets pouvant être couverts en une seule boucle constituent 66 % de l'ensemble des groupes de messages dans ces catégories. Cependant, des sujets ouverts peuvent parfois nécessiter plusieurs boucles, afin de bien définir le problème, d'établir une solution ou de pendre une décision. Dans le cas qui nous préoccupe, plus de 30 % des groupes de messages n'ont pu être complétés et ont été interrompus après une seule boucle. Les groupes de messages tombant dans les sous-catégories des directives, des demandes et des rapports spéciaux ont une caractéristique commune : ils contiennent des questions qui nécessitent une réponse ou traitent de problèmes qui doivent être réglés, et ce, dans un contexte décentralisé. Ces groupes de messages ont un contenu plus fonctionnel qui requiert une certaine interaction et des discussions entre les participants. L'objectif réel de ces groupes de messages est la demande de renseignements. Nos conclusions dans le présent cas suggèrent fortement que l'information est une ressource nécessaire dans le cadre d'un projet, voire un élément indispensable à la réalisation de celui-ci.

En se fiant au volet interactif des groupes de messages échangés, nous pouvons conclure que l'intégration, les approvisionnements et le matériel sont les trois principaux enjeux qui contiennent le plus grand nombre de questions et de problèmes d'ordre fonctionnel. Les processus de gestion de projet liés à l'intégration, aux approvisionnements et au matériel jouent un rôle majeur quant à la réalisation des travaux dans ce contexte décentralisé. D'autres travaux de recherche se sont penchés sur les questions et les problèmes d'ordre fonctionnel liés à différents processus relatifs à l'intégration, aux approvisionnements et au matériel. Trois listes exhaustives de problèmes signalés liés à l'intégration, aux approvisionnements et au matériel sont reproduites aux annexes A, B et C, respectivement. Plus important encore, nous avons constaté que les problèmes courants liés à ces enjeux sont un manque de sous-processus et de procédures bien définis, une confusion au niveau des rôles et des responsabilités, une mauvaise définition des besoins et des exigences en termes d'information et de communication ainsi qu'une méconnaissance des problèmes liés aux multiples sous-processus. Proposer des solutions appropriées afin de remédier aux problèmes, notamment aux problèmes courants, constituera le principal objectif des solutions proposées.

Solutions proposées

Les solutions proposées consistent en des modèles génériques, des modèles de cas d'utilisation et différents diagrammes à flèches liés à la gestion de l'intégration, des approvisionnements et du matériel. Les modèles génériques présentent l'enchaînement et la relation entre les sous-processus et les principales sources d'information à partir desquelles les modèles sont élaborés. Les principales sources d'information sont les entretiens et les autres discussions qui ont eu lieu entre les différents intervenants, les comptes-rendus d'autres études et les observations réalisées sur le cheminement de l'information entre les intervenants dans ce contexte décentralisé. Les modèles génériques proposés tiennent également compte des modèles existants définis par PMI (2004) ainsi que des pratiques exemplaires applicables au cas qui nous préoccupe.

Les modèles de cas d'utilisation définissent, à un haut niveau, les rôles de chacun des intervenants concernés et les responsabilités s'y rattachant. Chaque cas d'utilisation dans les modèles de cas d'utilisation correspond à un sous-processus proposé dans un modèle générique. Tous les cas d'utilisation, qui sont liés à un sous-processus qui, lui, est lié à la gestion de l'intégration, des approvisionnements et du matériel, sont élaborés minutieusement et formalisés dans des diagrammes à flèches. Les différents diagrammes à flèches établissent, quant à eux, les procédures et les éléments, et ce de façon précise, de chacun des sous-processus liés à l'intégration, aux approvisionnements et au matériel. Ces diagrammes à flèches, correspondant chacun à un sous-processus, constituent des solutions efficaces visant à régler les problèmes signalés liés à la gestion de l'intégration, des approvisionnements et du matériel, ainsi que d'autres problèmes courants.

CONTRIBUTION ET OBSERVATIONS FUTURES

La présente étude jette un éclairage sur les questions suivantes : (1) l'identification et l'établissement de structures relatives au cheminement de l'information dans un contexte distribué; (2) la reconnaissance de l'intégration, des approvisionnements et du matériel comme les trois processus de gestion les plus importants, lesquels soulèvent le plus grand nombre de problèmes qu'auront à régler les membres de l'équipe dans un contexte décentralisé; (3) l'examen des sujets contenus dans les courriers électroniques les plus interactifs en ce qui à trait à l'intégration, aux approvisionnements et au matériel ainsi que l'établissement de différents problèmes touchant les processus ou les sous-processus; (4) la proposition d'un modèle de sous-processus bien défini conçu pour remédier aux problèmes liés à la gestion de l'intégration ainsi que les améliorations possibles; (5) la proposition d'un modèle de sous-processus bien défini conçu pour remédier aux problèmes liés à la gestion des approvisionnements ainsi que les améliorations possibles; (6) la proposition d'un modèle de sous-processus bien défini conçu pour remédier aux problèmes liés à la gestion du matériel ainsi que les améliorations possibles.

Afin d'approfondir davantage nos travaux de recherche, nous invitons les chercheurs à se pencher sur les trois points décrits ci-après. En effet, il serait intéressant d'établir l'ensemble des structures relatives au cheminement de l'information dans le cadre de l'ensemble du projet, en observant les échanges entre un plus grand nombre d'intervenants, y compris les participants travaillant auprès du BGPI. Il serait également intéressant d'examiner en profondeur le mécanisme de prise de décision dans ce contexte distribué. Finalement, il serait important d'établir les besoins et les exigences pour un système d'information intégré et de proposer une solution appropriée qui corresponde et qui satisfasse aux exigences du projet.

CONCLUSION

Grâce à l'examen des courriers électroniques échangés, nous avons d'abord identifié et défini les structures relatives au cheminement de l'information lié à un projet de construction international réalisé dans un contexte décentralisé. Les enjeux qui se sont avérés les plus importants, si l'on se fie au volume du flux de l'information s'y rapportant, sont la communication, l'intégration, les approvisionnements, le matériel et les RH. Compte tenu du fait que la répartition du volume peut ne pas refléter la nature du sujet lui-même, nous avons procédé à un examen approfondi des courriers électroniques échangés, de façon à classer les messages selon les sujets abordés. Un modèle générique relatif au cheminement de l'information dans un contexte distribué a été conçu, afin de présenter le classement de tous les messages en deux grandes catégories, soit les demandes de renseignements et le partage de l'information. Comme la première catégorie semblait caractérisée par une interactivité plus importante, nous avons axé notre recherche sur celle-ci.

L'examen rigoureux de l'interaction et de la communication observées dans les groupes de messages a révélé que l'intégration, les approvisionnements et le matériel soulevaient le plus grand nombre de problèmes et constituaient les processus les plus importants en ce qui a trait à la réalisation du projet dans un contexte décentralisé. Les différents problèmes liés à l'intégration, aux approvisionnements et au matériel ont été observés, identifiés et définis. Nous avons pu conclure que les problèmes courants liés à ces trois processus découlaient d'un manque de sous-processus bien définis, d'une confusion au niveau des rôles et des responsabilités, d'une mauvaise définition des besoins et des exigences en termes d'information et de communication, et d'une méconnaissance des problèmes liés aux multiples sous-processus.

Le présent rapport propose et explique une série de modèles génériques, de modèles de cas d'utilisation et de diagrammes à flèches conçus afin de remédier aux différents problèmes liés à la gestion de l'intégration, des approvisionnements et du matériel ainsi qu'à d'autres problèmes courants. Les modèles génériques démontrent l'enchaînement et la relation entre de nombreux sous-processus liés à la gestion de l'intégration, des approvisionnements et du matériel, et les principales sources d'information à partir desquelles les modèles génériques ont été élaborés. Les modèles de cas d'utilisation définissent, à un haut niveau, les rôles et les responsabilités de tous les intervenants ayant à jouer un rôle dans la gestion de l'intégration, des approvisionnements et du matériel. Enfin, les diagrammes à flèches correspondant à chacun des sous-processus proposent des solutions efficaces aux problèmes signalés liés à la gestion de l'intégration, des approvisionnements et du matériel ainsi qu'à d'autres problèmes courants.

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2D CAD	Two-dimensional computer-aided design
3D CAD	Three-dimensional computer-aided design
APS	Application service provider
BPR	Business process reengineering
CO	Central office
CO-GM	Central office – General management
CO-PD	Central office – Project director
CPM	Critical path method
CSC	Construction supply chain
DPM	Dynamic planning and control methodology
ER	Enterprise resourcing
HR	Human resources
iPMO	International project management office
iPMO-PM	International project management office – Project manager
iPMO-SV	International project management office – Supervisor
PM-ASP	Project management system – application service provider
PMBOK®	Project management body of knowledge
PMI	Project Management Institute
PO	Purchase order
UML	Unified modeling language
WPMS	Web-based project management system

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CHAPTER 1
INTRODUCTION

1.1 Overview and research statement

Carrying out a construction project is a complex task. Organizations face even more challenges when the project to be executed is an international one. When delivering such a project internationally, an organization often needs to dispatch a group of its own personnel to the project site. The personnel in the international project management office (iPMO) and the project participants in the central office (CO) then work in a distributed team context. Even when all the project participants are co-located, due to the temporary and fragmented nature of construction projects, project team members have a real need for collaboration and information sharing to achieve success. The organization will have more difficulties with communication and coordination when the project participants are geographically dispersed.

In a real-life project executed in the international construction environment, what problems and difficulties will project participants have to face and overcome? What information flow patterns and features will be associated with the distributed team context? Where can we find evidence of those problems and difficulties? What approach or methods can be applied to identify and analyze the problems? What solutions can be proposed to help the project participants solve their problems and further improve their construction business processes? These are some of the questions underlying this research.

1.2 Research objective

The objective of this research is to analyze the management processes of a construction project in a distributed team environment, to identify the issues related to specific information flow processes and to propose ways of addressing those issues. Specifically, the objective consists in:

- Identifying the information flow patterns of a construction project in the internationally distributed work context;
- Analyzing the most relevant processes involved, and identifying the issues associated with those processes;
- Proposing appropriate solutions to address the identified issues and improve the efficiency of the project management processes.

1.3 Research scope

The proposed research will be restricted and limited to the following scope:

Principally speaking, the overlapping area of distributed context, international environment and construction industry forms the scope of the research work. This research scope is indicated in figure 1.1.

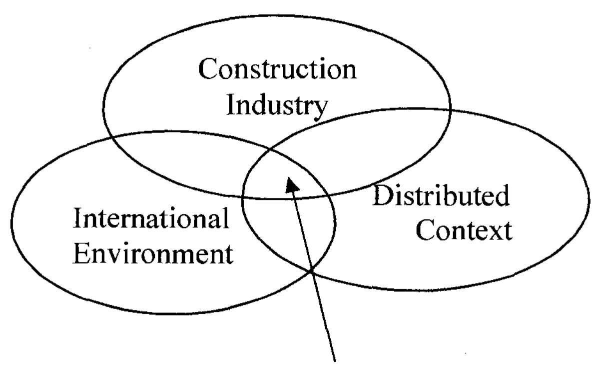

Figure 1.1 The scope of this research

More specifically, the research will observe the email messages exchanged between the site project manager and other project participants within a distributed team in an international construction environment. The research will focus on the case study of a medium-sized agricultural project provided by a Canadian supplier and installed in China. The duration of the observation period was from January to December 2005 when all the construction project deliverables were physically completed.

The research will identify the information flow patterns and the issues related to various critical management processes and propose new blueprints for improvement of the critical processes identified. The study examines a distributed team context in which the project participants worked in two main locations. One is in China, where the construction project was physically built, and another in Canada, where the central office of the organization executing the project is located.

1.4 Thesis structure and organization

Chapter 1 introduces this research. This chapter presents a description of the research problem, the objective of the research and the research scope. Chapter 2 contains the literature review. This chapter summarizes recent work by various researchers which is relevant to our research topics, identifies gaps in the existing body of research, and establishes the scope and problems of our research. Chapter 3 presents the methodologies that were applied in this research.

Chapter 4 presents the results of our research work in this report. This chapter consists of three main parts. The first part presents the international construction project that is used for case study and observation. This section provides the contextual background information about the case project. The second part analyzes the email messages exchanged at the iPMO project management level and establishes the information flow patterns. The third part observes the purpose of information flows in the distributed context and finds that integration, procurement and materials are three critical processes that have the most issues. This chapter also further reviews the content of the messages in the selected categories and identifies the nature of the observed issues.

Chapter 5 discusses and analyzes the issues associated with the selected processes and proposes appropriate models, formalized by UML modeling, to address the identified issues. Chapter 6 illustrates research contributions, limitation and implications for future research. Chapter 7 presents the conclusion of this research work.

CHAPTER 2
LITERATURE REVIEW

In order to identify any research gaps within the existing research, this chapter conducts a review of the relevant literature. The relevant review areas involve information flows in construction projects, distributed team contexts in the construction industry, and construction process reengineering and modeling.

2.1 Information flows in construction projects

2.1.1 Definitions

Information transfer and exchange is closely correlated with communication. Communication in general has a very broad meaning. One definition from the Merriam-Webster dictionary (1994) is that communication is "a process by which information is exchanged between individuals through a common system of symbols, signs or behavior." In the same dictionary, information is defined as "the communication or reception of knowledge or intelligence." According to these definitions, communication is not to the same as information itself. Instead, this definition emphasizes that communication relates to physical media and means for information transfer and exchange. In the project management field, specifically, the PMI (2004) states that "communication is a process required to ensure timely and appropriate generation, collection, distribution, storage, retrieval, and ultimate disposition of project information". This definition further clarifies the function of communication in terms of information generation and distribution. Because of the close relationship between the two words and concepts, the literature review also includes studies of communication in the construction industry.

Delivering the desired project on time, according to the defined quality, and within budget is the primary mission of any project team. To achieve this goal, effective communication within the project team and with all of the associated stakeholders is essential. According to Levin (2005), in a project context, communication is the transfer of some type of message that contains one or more pieces of information. The information can be conveyed through formal or informal channels. Equal in importance to labor, material, equipment and capital, information has become a key to project implementation. As Hiremath and Skibniewski (2004) argue, the management of project information sources is just as important as managing other key sources. Mohamed and Stewart (2003) argue that timely and accurate information transfer and sharing is important for all project participants as it forms the basis on which decisions are made and physical progress is achieved.

2.1.2 Role in construction

Many researchers have investigated the critical factors that influence project success in the construction industry. The study by Yu, Shen, Kelly, and Hunter (2006) confirmed that open and effective communication, and clear and precise briefing documents are the top two of the 15 critical success factors that contribute to a successful construction project briefing process. Similarly, Belout and Gauvreau (2004) observed the impact of human resource factors on project success, and found that communication is one of three primary factors that are significantly correlated with project success in construction. Compared with communication, information is also a critical factor to determine the success of project execution. Cleland and Ireland (2002) emphasized that accurate and timely information is essential for the management of a project.

At the same time, various researchers have observed the different types of information associated with the communication process in a project execution context. Dawood, Akinsola, and Hobbs (2002) proposed that construction information includes general information, organization-specific information and project-specific information. General information refers to publicly or commercially available information concerning construction products, regulations, standards, procedures, etc. Organization-specific information involves all information available to a specific organization such as standard solutions to design construction problems. Project-specific information is associated with one construction project or project type, and shared by several organizations that make up the supply chain. The information flows associated with inter-organizational communication are the key to project information management (Mohamed & Stewart, 2003).

Any information that is conveyed must be in the form of certain data types and formats. As Caldas, Soibelman, and Han (2002) point out, construction information is related to a variety of data types, including structural data files, semi-structural data files, unstructured text data files, unstructured graphic files, and multimedia files. When planning the construction process, the project team has to identify and collect information such as the duration of each project task, the availability and allocation of resources, and the dependence between project jobs. In this case, information serves as the basis for generating project work plans, schedules, resource usage, network diagrams and other planning components. Again, when project principals review a project's status and progress, they often require their project team on the construction site to provide various reports such as weekly reports, picture reports, project performance reports, etc.

Usually, different kinds of information are stored in different file formats, and often located in different organizations, computers and file systems. The project examined in this case study provides a real example of such a situation. The design information for this construction project was stored and updated at the central office in Canada, whereas information related to construction execution was documented and collected at the project site office in China. Project participants have an essential need to acquire and share information from different formats and sources. Further, considering that projects are designed, built and maintained using dynamic processes, project participants have to face a huge challenge throughout the whole construction life cycle. Project teams and their principals require effective and efficient communication and information to identify any deviations due to changes and make the necessary adaptations to handle the new situation. Unfortunately, poor information systems and processes are still very common.

2.1.3 Problems in the construction industry

In industry practice, inadequate coordination and inefficient means of communication of project information and data have been found to cause more than 60% of construction problems (Dawood et al., 2002). The need for improved project communication has become a widely documented issue in the construction industry (Mohamed & Stewart, 2003). However, as Mohamed and Stewart (2003) observed, no matter how much effort a project team has put into the designing and planning process, it has to face various problems and issues that call for immediate attention as soon as the construction work starts. In such a dynamic construction environment, project participants tend to become less careful about passing on their information. In this case, the project team and the principals may face serious consequence in terms of information flows. For instance, if they do not have the same understanding of information transfer procedures, some team members will not be appropriately informed. Low communication efficiency and information confusion cannot be avoided. Without constant and effective information flows, the project is likely to fail.

Further, as Wikforss and Lofgren (2007) found, the distribution of information and cooperation within a project will be badly affected if different participants focus on different areas and have different, sometimes conflicting, interests. In such case, a common goal for achieving project success is hardly likely to be achieved. To find the root cause of various project management problems, some researchers have reported on different issues and problems affecting information flows in the construction industry. Hiremath and Skibniewski (2004) showed that a lack of clear scope and many inconsistencies in the drawings become a fertile breeding ground for change order proposals. In their study, the construction manager found it extremely difficult to effectively control the mad rush for information and subsequent claims from the contractors.

Decelle and Young (2005) carried out a comparative review of supply chain communication in both the manufacturing and construction industries. They identified problems related to information flows including incorrect documents, design changes, engineering drawings that did not fit their intended use, information needs not met, etc. The interfaces affected by those problems involved engineering and purchasing, subcontractor and site, supplier and site, etc. Decelle and Young noticed that communication problems formed a significant proportion of all the problems faced in construction supply chains.

By means of structured questionnaires and interviews, Shohet and Frydman (2005) observed communication patterns at the construction management level in a traditional project management context and environment. Their findings reveal that the most important topics related to information flows are construction instruction, materials and equipment, quality management, allocation of manpower, and cost control. Studies have been done of construction problems and issue identification and discussion, but studies focusing on a detailed analysis of information flows are still scarce (Akinci, Kiziltas, Ergen, Karaesmen, & Keceli, 2006). Accordingly, extending the earlier research efforts by investigating information flows, and the issues associated with information flows within a real project execution environment will be essential.

2.1.4 Information system application in the construction industry

2.1.4.1 Overview

Construction projects are unique and the production process varies from one to another. Since many stakeholders and different phases are involved in a construction project, the construction industry is fragmented. There is no one-size-fits-all solution to the industry's problems (Dawood et al., 2002). Therefore, it is very difficult to develop a comprehensive information system that will encompass all types of construction projects, project organizations and construction company contracts. With the involvement of entities from different countries, and participants from different cultures, with diverse local regulations and requirements, information flows in a major internationally executed project are even more complex (Hiremath & Skibniewski, 2004). To achieve the goal of improving communication by using available IT facilities and technologies, the key issues have to be confronted. An understanding of the processes involved in the production of a project and formalisms for the sharing and exchange of information and data are the two key issues in the construction project environment (Dawood et al., 2002).

2.1.4.2 Applied information systems

Nitithamyong and Skibniewski (2004) showed that information technology is routinely used in the construction industry as a tool to reduce some of the problems resulting from fragmentation. For instance, Hegazy (2002) recommended a spreadsheet program as a simple and effective tool that has all the powerful functions needed to satisfy the demands of construction applications to improve the quality, integrity and timeliness of construction data. Regarding project management software, Hegazy recommended Microsoft Project and Primavera as the planning and tracking tools to make it easier for project teams to set up a project plan, allocate resources, assign responsibility and follow up on the construction process.

In fact, construction projects, especially large ones to be executed in an international construction environment, involve many different phases such as conception, design, construction and operational testing, and many aspects such as material inventory and control, purchasing orders, human resources recruitment and hiring and so on. As the one-fit-all solution and information system does not yet exist, there is a strong need for using different specialized information systems or technologies to satisfy the specific requirement associated with different construction phases or aspects.

Rivard et al. (2004) conducted case studies on the use of information technology in the Canadian construction industry, and highlighted the application areas or domains in construction with different information systems or technologies. The technologies they discussed include 3D CAD, custom web sites, commercial web portals, and in-house software development. One CAD tool used in the industry is MicroStation, which offers a more comprehensive and simpler approach for creating and simulating 3D models. AutoCAD is selected as a 2D tool to receive the data exported from MicroStation to prepare plans, sections and details. Compared with 2D CAD tools, 3D CAD software possesses various functional advantages. 3D models help the project stakeholders to better visualize the planned building or systems, and identify and resolve the errors that are not easily detected in traditional 2D CAD tools.

2.1.4.3 Web-based solutions

Due to the accelerated development of network technologies, an increasing number of building projects have used a project web site as a tool to increase the efficiency of digital data exchanges between the companies involved (Andresen, Christensen, & Howard, 2003). Custom project web sites adjust better to the particular needs of the company. When choosing this approach, companies have to consider that a custom web site usually demands considerable resources for development, training, operation and maintenance (Rivard et al., 2004). In addition, Andresen et al. (2003) identified a few further barriers to using a project web site. One important issue in using project web sites is how to identify and determine the objectives. The second issue is that the companies involved need to specify how each one should use the project web site. The third issue is what legal status the project web site will have when paper versions are considered as the legally binding documents.

A number of companies nowadays are considering a web portal. A web portal is a web site that provides a wide array of resources and services to attract and keep a large audience, aiming to become its main entrance to the Internet (Rivard et al., 2004). The functions that a web portal may provide include project hosting, online meetings, searching trade directories, bidding, procurement, search engines, and so on. Web portals could play a more effective role during construction projects in order to take advantage of the construction management competencies offered by commercial web portals. However, the portals were not used as extensively as planned in some of the cases observed by the researchers. For instance, one obstacle is that most subcontractors do not possess the technology for online tending for a bidding process. In such cases, if online bids are posted, many qualified subcontractors are not able to participate and the bidding process become less competitive. When companies cannot find appropriate software from vendors to address their particular needs, developing an in-house system may prove a demanding endeavor.

Among the information technologies mentioned by Rivard et al. (2004), one concept of how the web and its associated technologies can be applied to manage construction projects has been widely acknowledged by practitioners (Nitithamyong & Skibniewski, 2004): Web-based Project Management Systems (WPMS). Many other researchers have also proposed and developed various web-enabled or Internet-supported information systems to address the needs generated by construction projects. For instance, Lee, Pena-Mora, and Park (2006) developed a web-based Dynamic Planning and Control Methodology (DPM), which is able to capture feedback processes caused by errors and changes and smooth transactions among geographically distributed participants during the design and construction processes.

The Internet-based system proposed by Chim, Anumba, and Carrillo (2004) can significantly enhance collaborative decision-making by a geographically distributed construction project team. Zou and Seo (2006) undertook an extensive review of the application of e-commerce technologies in construction supply chains. Based on information sharing over the entire project life cycle, Wang, Yang, and Shen (2007) built an information integration model for e-commerce in the construction industry, and Ingirige and Sexton (2007) observed the advancement, capabilities and barriers to intranet applications in large construction organizations.

According to Nitithamyong and Skibniewski (2006), there are three options for WPMS implementation. The first is to develop an in-house customized WPMS. The second option is to purchase commercial web-based software and install it on a company's internal server. The third option is to rent a completely developed WPMS from an Application Service Provider (APS). Of the three options, the researchers highly recommend the third, referred to as "Project Management System-Application Service Provider" (PM-ASP). The advantage is that this option requires minimal technical, financial and human resources to develop and operate. However, there are various key factors that may determine the success or failure of WPMS implementation. Construction organizations that expect to adopt WPMS must carefully study those factors so they can operate such systems more productively and efficiently.

2.1.5 Summary

Information flows are the critical factor that determines the success of construction project execution. It is essential for researchers to observe and identify the issues and problems associated with information flows within a real project execution environment in order to propose appropriate solutions to address those issues and achieve project success.

Due to the fragmented nature of the construction industry, there is no one-size-fits-all information system. In current practice, different specialized information systems or technologies are applied in order to satisfy the specific requirements associated with different construction phases or aspects. One new application trend is that an increasing number of building projects have used a project web site as a tool to increase the efficiency of construction processes. To achieve the goal of improving communication by using available IT facilities and technologies, it is essential to understand the processes involved in the production of a project and formalize information and data sharing and exchange processes.

2.2 Distributed team contexts in construction

2.2.1 Definition

The increase in the globalization and complexity of construction projects has motivated the participation of companies from dispersed geographic areas in project teams (Caldas et al., 2002). More and more project teams have to work in a distributed context. Project teams working in distributed contexts will face different challenges from those in traditional co-located project contexts. When working in a traditional project environment, co-located project team members are in physical proximity. This traditional project work context reinforces social similarity, shared values and expectations common to all the participants performing the project work. However, the traditional process of walking someone through the comprehension of a topic obviously does not exist in a distributed context, at least not in the same form (Levin, 2005).

Distributed teams are defined as geographically and/or organizationally dispersed groups of coworkers who use a combination of telecommunications and information technologies to accomplish an organizational task. Distributed teams are also referred to as globally dispersed or virtual teams (Dekker & Rutte, 2007). Some studies emphasize that distributed teams are located in a real-time collaborative work environment, in which collaboration technologies are characterized by the capacity to permit synchronous manipulation of common project data (Chinowsky & Rojas, 2003).

As a new kind of work form, distributed teams face significant and immediate challenges in organizing and communicating (Suchan & Hayzak, 2001). Without effective communication, project members in a distributed context cannot understand each other properly, and they will definitely face difficulties in working efficiently together towards a common project goal. The ability to communicate is one of the key success factors for the project performed by the distributed team (Nurmi, Marttiin, & Rossi, 2007). There is a wealth of research on communication in a distributed context (Amponsah, 2003; Hart-Davidson, 2003; McKinney & Whiteside, 2006; Powell, Piccoli, & Ives, 2004) and some studies on communication and communication systems in the construction industry (Dawood et al., 2002; Gillespie, 1996; Shohet & Frydman, 2003). All these studies suggest that the topic of distributed teams has attracted more attention in the management literature.

2.2.2 Dimensions of the distributed team

Evaristo, Scudder, Desouza, and Sato (2004) conducted a dimensional analysis of geographically distributed project teams by observing a real case. The objective of their research was to understand exactly what "distributed" means when discussing the management of distributed teams. The dimensions for the measurement of distributed contexts include trust, perceived distance, level of dispersion, synchronicity, type of stakeholders, complexity, culture, type of project, system methodology and existence of policies and standards. Among all these factors, perceived distance, level of dispersion and synchronicity are the dimensions that distinguish distributed teams from conventional face-to-face teams (Hertel, Geister, & Konradt, 2005).

In addition, Hertel et al. (2005) pointed out that communication and coordination predominantly based on electronic communication media is another distinguishing feature of project teams working in the distributed work context. Due to this distributed nature, distributed team members have to rely heavily on information and communication technologies (Powell et al., 2004). Such information and communication technologies establish and maintain links among all associated parties across distance, time, culture, department, and organizations. This creates "anyone/anytime/anyplace" alternatives to the traditional same time, same place, functionally centered, and in-house forms of organizational experiences (DeSanctis & Monge, 1998).

2.2.3 Communication media

Communication media are physical means or mechanisms by which a communication process can be established and maintained. Communication media are divided into three categories: traditional, electronic and connecting (McKinney & Whiteside, 2006). Face-to-face meetings and letters are examples of traditional media. Electronic media refer to email and videoconferencing, whereas connecting media include phone conversations and fax transmittal. Media richness theory concludes that different media possess different levels of richness in terms of information flows (Lancaster et al., 2007). Face-to-face communication is commonly perceived as substantially richer than any other medium. Due to the lack of face-to-face communication in a distributed work environment, distributed project teams have to face considerable challenges to effective communications, including time delays in sending feedback, lack of a common frame of reference for all members, difference in salience and interpretation of written text, and assurance of participation from remote team members (Powell et al., 2004). Although there exists a difference in richness between different communication media, their selection and use must depend on their fit and availability to the communication objectives and requirements (Hertel et al., 2005). Hertel et al. (2005) highlight the importance of the fit between communication media and communication content and requirements.

The current literature is still poor at showing features of information flows in the distributed team context within a construction project. Nurmi et al. (2007) investigated communications over the project life cycle and their research improves our understanding of how the different categorized topics are emphasized and how the emphasis changes over the time. However, their research project was carried out in a university context and that setting has limitations for reflecting real information flows in a distributed teamwork context. Factors such as human resources and quality, which are essential to project management, are not integrated into the processes observed in their research.

2.2.4 Summary

Despite the growing prevalence of distributed teams as a new work form, very few studies have been conducted about the information flow patterns and the problems associated with information flow processes in a distributed construction project. Most researchers studying the construction industry focus their research efforts on observing the various features associated with real-time collaboration within a distributed team. For instance, Chinowsky and Rojas (2003) proposed that, in an optimal collaboration scenario, project participants are able to communicate visually and orally, in addition to their shared data exchange and manipulation capability. Similarly, Chim et al. (2004) developed a collaborative decision-making system that could ease the difficulties experienced by geographically distributed construction project team members. Compared to the work by Chinowsky and Rojas (2003), the research by Chim et al. (2004) is more focused on the decision-making process in a collaborative environment.

Among all possible influencing factors, a key enabler of successful collaboration is the ability to communicate and share and exchange project information in a timely and accurate manner (Mohamed & Stewart, 2003). For traditional teams, synchronous interaction is the primary means of collaboration and the notion of chronological time is not a challenge. However, distributed teams are rarely fully synchronous and they usually have limited time to establish and maintain real-time collaboration. Work performed by time-dispersed team members often needs to be resequenced to incorporate time lags. The idiosyncratic nature of the distributed work environment creates a fertile ground for future research. Distributed team research should explore the notion of time dispersion and the role of time in distributed team communication processes (Powell et al., 2004). Further, distributed teams studied to date have shown that formalization of managerial structure or working procedures is lacking. More importantly, distributed team research to date has not questioned the applicability of traditional team process view to the virtual environment. Information system researchers, with their understanding of new technology, organizational structures and social systems, and their experience studying the introduction and adoption of new technologies, are well positioned to explore novel approaches to virtual team operation and management.

As a new work form, distributed teams face significant and immediate challenges in communication and organization. Ability to communicate becomes a key success factor for the project performed by the distributed team. Currently, there is a wealth of research on communication in the distributed work context. However, in a distributed construction project environment, especially within asynchronous teams, research on information flow patterns, and the problematic issues associated with the information flow processes, is very rare. The establishment of appropriate information flow patterns within distributed work contexts for a construction project will make a significant contribution to the research literature. The further identification of various issues associated with information flows will help distributed teams to visualize and improve their project management processes.

The literature review in this section has mainly focused on a few significant topics relevant to distributed teams in the construction industry. However, this review would not be complete without considering the processes associated with construction project execution. Accordingly, the literature reviewed in the next section will mainly consider construction process reengineering and modeling.

2.3 Construction process reengineering and modeling

2.3.1 Overview of modeling in construction

Previous researchers have developed many different models of construction projects. The same physical world can be described from different perspectives. Process modeling is one popular approach to define and formalize the construction process. Process models form the basis for reasoning about and modifying existing business processes, leading to the development of the concept of business process reengineering (Lu & Issa, 2005). This concept appeared in 1990, and the core areas associated with it include process reorganization, use of information technology, and organizational redesign (Cheng, Tsai, & Xiao, 2006).

Business model developers have specific purposes for developing and performing modeling. Reviewing the various existing models from the perspective of these purposes will lead to an in-depth understanding of their natures and features. Based on a survey and interviews with the members of the Australian Computer Society, Davies, Green, Rosemann, Indulska, and Gallo (2006) obtained data on the various purposes for which people might undertake modeling and presented a purpose use list in rank order from the highest to the lowest. The top ten purpose uses on the list were database design and management, business process documentation, improvement of internal business processes, software development, improvement of collaborative business processes, workflow management, design of enterprise architecture, change management, knowledge management and end user training. In addition, human resource management and simulation are other two important purposes for which people undertake modeling.

Most of the above-mentioned purposes also remain important research topics for researchers in the construction industry, as indicated on table 2.1.

Table 2.1 Modeling purposes for construction projects

No.	Modeling purposes	Researchers
1	Construction supply chain management	Xue, Wang, Shen, & Yu (2007)
2	Change management	Hiremath & Skibniewski (2004) Lee et al. (2006) Lee, Pena-Mora, & Park (2005) Motawa, Anumba, & Pena-Mora (2007) Park & Pena-Mora (2003)
3	Simulation	Cheng, Feng, & Shu (2006) Fan, Tserng, & Wang (2003) Waly & Thabet (2003) Zhang, Tam, & Li (2005)
4	Resource allocation and management	Cheng et al. (2006) Childerhouse, Lewis, Naim, & Towill (2003)
5	Data and knowledge management	Czuchry & Yasin (2003) Dawood et al. (2002) Pektas & Pultar (2006) Reich & Wee (2006) Snider & Nissen (2003) Stumf, Ganeshan, Chin, & Liu (1996) Tserng & Lin (2003)
6	Collaborative business process improvement	Chim et al. (2004) Lu & Issa (2005) Mokhtar, Bedard, & Fazio (1998) Rezgui et al. (1996) van Leeuwen & Fridqvist (2006) van Leeuwen & van der Zee (2005) Zhu & Augenbroe (2006)
7	Software design and development	Cetiner (2004) Deng, Li, Tam, Shen, & Love (2001) Hadikusumo, Petchpong, & Charoenngam (2005) Kim, Lee, Kim, Shin, & Cho (2005) Navon & Berkovich (2005) Zhu & Li (2007)

Of all these modeling purposes, change management, resource allocation and management, data and knowledge management, and collaborative business process improvement are most relevant to the research topics identified in this report. This section will focus on a more detailed review of the existing research related to these modeling purposes.

2.3.2 Change management

Change management has been the focus of various construction processes. The literature on change management and evaluation mainly involves the identification of change processes, best practice recommendations for managing change during the life cycle, and the evaluation of the effects of change on single project parameters. Change management is a significant subject that receives substantial attention from researchers working on the construction industry.

Construction changes refer to work states, processes, or methods that deviate from the original construction plan or specifications (Park & Pena-Mora, 2003). Various unique features associated with the construction project environment may lead to changes being requested during the construction process. Construction is dynamic process-based work carried out in an open environment and performed in an unfixed place by a temporary alliance of different organizations. At the same time, the scope of construction projects varies greatly. Due to these dynamic features, human responses to the work environment and managerial decisions are highly unpredictable. Therefore, to assist project teams in executing project tasks effectively and achieving the final project goal successfully, research into change management must be able to identify the various changes and propose appropriate solutions to reduce their impacts on the project implementation.

Park and Pena-Mora (2003) noted that, during the construction process, changes occur either on purpose or unintentionally. Unintended changes may result from low work quality, poor work conditions, external scope changes, and hidden upstream changes. Unintended changes do not involve the intervention of managerial actions. Unlike unintended changes, management changes are part of the quality management process, which may involve managerial decisions. During quality management, rework is an available option that is done on problematic tasks to achieve what had originally been expected in the plan and specifications. The primary difference between rework and managerial changes is that the former does not trigger any subsequent changes in other tasks. Based on their observation of the change generation mechanism, the researchers developed a dynamic construction project model that focused on effective change management and construction policy making.

Lee et al. (2005) further observed that construction projects involve multiple feedback processes that trigger the uncertainty and complexity of design and construction projects. Such multiple feedback processes are caused by errors and changes, which usually occur as iterative cycles, in the complex interrelationships of project activities. To identify the interconnection and interaction of the various components, the researchers proposed a framework for quality and change management to investigate the generation and management of iterative cycles caused by errors and changes. Further, the same research group developed a system, named dynamic planning and control methodology, which is capable of analyzing error and change cycles and is applicable, practically and smoothly, to real-world projects. Their system dynamic project model emphasizes the unique characteristics of errors and changes in design and construction projects, and is able to compute their impact on construction performance by focusing the issue of capacity utilization.

As little attention has been paid to modeling the dependent data or simulating the iterative cycles of concurrent design and construction that result from unanticipated changes and their subsequent impacts on project performance, the research by Motawa et al. (2007) focused on modeling this dependency, especially for multiple causes and effects, and planning such iterative tasks.

2.3.3 Resource allocation and management

For a project team, a resource is an essential input to any project task or activity. Cheng et al. (2006) applied business process reengineering (BPR) to analyze construction business processes and developed a team-based human resource planning method to deploy labor. BPR is not a new topic. But the construction industry has arguably lagged in implementing it (Childerhouse et al., 2003). To implement BPR to fulfill a specific business goal, existing activities and procedures in different functional departments must be integrated into a single complete process. For instance, the study by Cheng et al.

(2006) focused on human resource planning by applying the BPR method. By using their method, a construction project team can design a team-based organizational structure and can also allocate human resources based on cross-functional processes.

Similarly, the research by Childerhouse et al. (2003) focused on observing problematic issues faced by a medium-sized European industrial enterprise and applied BPR to address these problems and improve construction business processes. Their approach involves four BPR stages. The first stage found that just-in-time manufacturing is an effective solution that reduces lead times via cellular manufacturing. The second stage highlighted the importance of coordination of purchasing operations and emphasized supplier integration by appropriate interface and interaction design. The third stage is a logical progression in process reengineering, taking the established relationships one step further and adopting just-in-time procurement. To improve and maintain operational efficiency, the fourth stage highlighted custom integration and aimed to move beyond the internal supply chain by including external customers and suppliers.

2.3.4 Data and knowledge management

Data management involves many individuals and organizations exchanging a lot of information at different times and locations (Stumf et al., 1996). The important outcome of the research by Stumf et al. (1996) is the development of an integrated data model that incorporates and processes information to support collaboration among design and construction teams. However, due to the complex nature of the construction industry, different projects may face different data and communication issues or difficulties. For instance, in a multiple-contract project environment, participants need to acquire external real-time scheduling data from other parties involved and use this data to make appropriate decisions regarding project control (Tserng & Lin, 2003). In such cases, the variety of data structures that the project may use and the lack of an automatic mechanism for data acquisition are the two main obstacles to the project participants when they wish to gain efficient access to external information in a distributed data environment.

To solve such problems, Tserng and Lin (2003) developed an automatic communication environment for multiple-contract projects and helped the project participants to communicate effectively and get the information they needed more efficiently. This kind of automatic communication environment further highlights the fact that data is essential to project executives and managers operating in today's global environment. To achieve this goal, Czuchry and Yasin (2003) present an executive scoreboard model that includes the measurement of profitability, growth, innovation, risk taking, customer satisfaction, employee satisfaction, organizational effectiveness, and supplier partnership success. The three models comprise decisional factors, critical skill and technical know-how. To assist the project executive and managers in knowing when and how to drill down into the detail needed to assess the root causes of potential operational problems and solve them to guarantee project success, an informational integrated model is proposed and recommended by the research.

So far, many researchers have developed and proposed integrated process models. However, many of those proposed models are not able to formalize how communication and data exchange within the construction process can be achieved, without duplication or loss of quality (Dawood et al., 2002). To overcome the limitations on existing models, Dawood et al. (2002) developed a methodology and a system that will ease and improve communications and data and information exchanges between construction project team members. After observing the problems associated with the paper-based drawing management process, the researchers proposed a data model to illustrate the reengineered drawing management process. The new system provides storage and immediate access for viewing, printing or downloading to make changes. It also saves both time and money by eliminating duplicated information.

In addition to data exchange and communication, knowledge transfer and flow is another important aspect that draws researchers' attention for observation and studies. From the perspective of knowledge management, a project's primary task is to manage the team members' and stakeholders' knowledge bases so that they can combine in the best possible way to successfully accomplish their assignment (Reich & Wee, 2006).

Considering that knowledge management is largely ignored in the globally influential PMBOK®, as defined by the PMI (2004), Reich et al. (2006) proposed knowledge as the tenth area for the *PMBOK® Guide,* adding new processes that run parallel to those of the other nine knowledge areas.

The proposed knowledge management model includes Plan Knowledge Management, Identify Knowledge Requirement, Integrate Knowledge, and Store and Disseminate Knowledge. However, the limitation on the model proposed by Reich et al. (2006) for the PMBOK® is that its generally static and explicit nature is out of phase with the dynamics of critical tacit knowledge as it flows through the project organization (Snider & Nissen, 2003). To reflect the dynamic nature of knowledge flows, Snider and Nissen (2003) outlined a knowledge flow model that allows for the incorporation of a variety of knowledge flows. The contribution made by those researchers is that their knowledge flow model constitutes a rich and robust foundation for project management research and practices.

2.3.5 Collaborative business process improvement

Construction projects typically require the involvement of a large number of participants who have to work together on design and construction. When the participants are not co-located on a daily basis, effective cooperation and collaboration among different participants will be critical to the project's success (van Leeuwen & Fridqvist, 2006). Identifying problems and finding the right solutions will be essential to maintain and improve the appropriate concurrent and collaborative work environment. The overall aim of project modeling in concurrent and collaborative work contexts is to improve the long-term effectiveness of the construction industry by allowing for the intelligent integration of information for effective project management (Rezgui et al., 1996).

Modeling for concurrent and collaborative work context is a very important research subject that has been investigated by various researchers. Mokhtar et al. (1998) observed the building design process and found that common problems included inconsistent design information, mismatches between connected parts, and component malfunction.

Their model uses a central database, which is developed not only to carry the building component data, but also to allow these components to actively assist the coordination process.

In the collaborative work context, the quality and availability of information are crucial to all participants. Van Leeuwen and van der Zee (2005) use the concepts of semantics, validity, format, and timeliness to measure and determine the value of production information for design. They observed that a major disadvantage in current practices is that the information distributed detaches from the business process. In terms of information, their model emphasized that "distributed" means "accessed by many information providers," rather than "sent to many information clients." Their later research work reinforced the collaborative work environment by providing remote data access, allowing users to share resources and remain active at their source, closely related to real-life business processes (van Leeuwen & Fridqvist, 2006). The advantages of their proposed approach and model include integration of business processes through data sharing, enhanced consistency and reduced redundancy, control of information remaining with the owner, etc.

When construction teams work in a geographically distributed context, collaborative decision-making can become challenging. To ease the difficulties experienced by such distributed teams, Chim et al. (2004) proposed an Internet-based collaborative decision-making system for the construction industry. By means of such a system, distributed project teams are able to establish and maintain links and communication for a collaborative decision-making process. Another issue in a collaborative work environment, as Lu and Issa (2005) observed, is that there are obvious limitations due to the implementation with closely coupled collaboration. Lu and Issa (2005) built a loosely coupled system in which participants have safeguarded, clearly defined boundaries between them to protect their internal operations.

2.3.6 Summary

All model developers have their specific reasons for developing and using a model. Among these purposes, change management, resource allocation and management, data and knowledge management, and collaborative business process improvement are most relevant to the research topics identified in this report. This section focused mainly on a more detailed review of the previous studies related to these purposes.

The literature review reveals that various models have been developed to address issues associated with different aspects or processes of project execution. However, business model development and application for cooperation and communication in a totally asynchronous and geographically distributed context within a construction environment is largely ignored. What problematic issues may distributed teams face? How can researchers take advantage of the modeling technique to identify those issues and find solutions that will improve project management processes? These aspects will remain interesting topics for further research.

2.4 Summary of literature review

The literature review in this chapter mainly addresses information flows in construction projects, distributed team contexts in the construction industry, and construction process reengineering and modeling. After this systematic review of the existing literature, certain research gaps have been observed and identified.

More specifically, studies of information flow patterns and the problematic issues associated with the information flow processes in a distributed construction project work environment, especially within asynchronous teams, are very rare. Furthermore, business model development and application for cooperation and communication in a totally asynchronous and geographically distributed context within a construction environment is also largely ignored. The establishment of appropriate information flow patterns within distributed work contexts for a construction project will make a significant contribution to the research literature. The further identification of various issues associated with information flows, and new models to address such issues will make it easier for distributed teams to visualize and improve their project management processes accordingly.

To achieve such research goals, the next chapter will identify and establish the appropriate research methodologies.

CHAPTER 3
RESEARCH METHODOLOGIES

In chapter 2, research gaps were identified based on a literature review. These identified gaps will become the research objectives in this report. To achieve these goals, this chapter will identify and establish appropriate research methodologies.

3.1 Research process road map

Figure 3.1 presents the research process road map that sets out the specific methods applied at each research step. The road map depicts seven steps. In step 1, all email messages are divided into two main groups. One group contains the messages associated with the local context where the project site office is located. Another group includes the messages related to the distributed context in which the project participants at the project site in China communicate each day with the project principals at their central office in Canada. This first classification into two main groups is required in order to define the scope of the research. In step 2, all email messages in the distributed context are reviewed in order to observe the overall information flow in the distributed context. As email is the primary communication medium among the project stakeholders in the distributed context, the messages in this group will contain and represent the overall information flows in the distributed context.

In step 3, all the messages are further classified according to the PMBOK® framework. Further classification is required in order to (1) limit the scope of the research; (2) visualize the construction business process; and (3) establish the information flow pattern in the distributed context. In step 4, all emails related to integration, materials and procurement are selected and observed. The selection of these categories is based on discussions with project participants and observation of the interactive features of different message groups. In step 5, the contents of the extracted lists of emails are reviewed and issues related to construction processes are identified. This analysis of the contents is required in order to identify the nature of the issues.

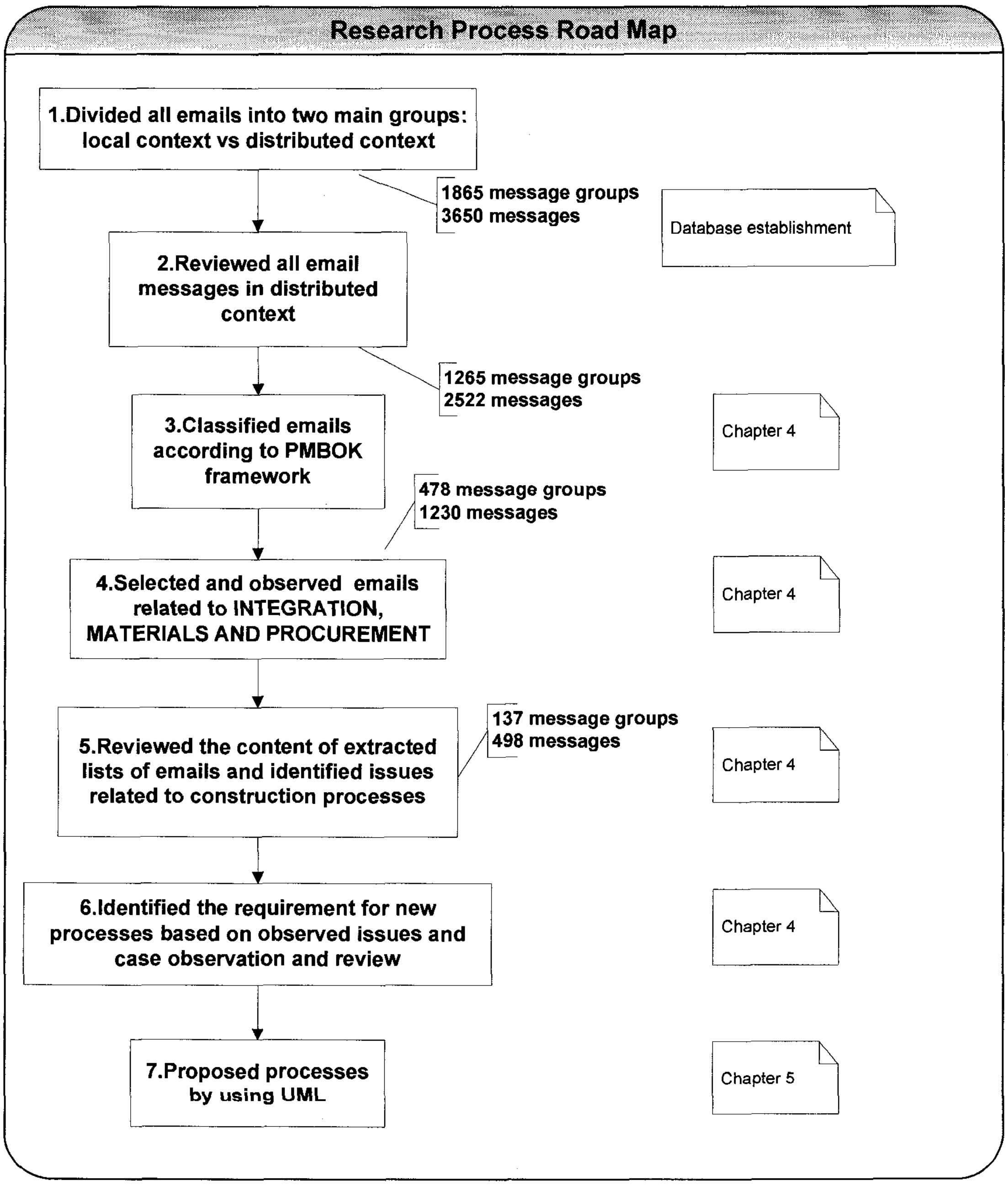

Figure 3.1 Research process road map

Step 6 identifies the requirements for new processes based on the observed issues and the case observation and review. Requirement identification is necessary in order to define the scope of the solutions. The last step, step 7, proposes new processes by using Unified Modeling Language (UML) while taking existing models into account.

3.2 Case observation and data source

The data that we analyzed constitutes all of the archived email communication files[1] of the iPMO project manager for the whole year of 2005, which covered the project phases from construction execution to construction closure. Accordingly, the data used to observe the project came from two main sources. First, the archived files containing all email messages exchanged between the project's actors were made available by the firm; these comprised most of the communications between people at the project site (China) and other project participants and stakeholders, including the project director and general management located in the Canadian head office. The data also contains email exchanged with the project's customer and various suppliers. The archived email file contains 3650 exchanged email messages.

Using email messages is a particularly effective data collection strategy in a distributed work context, where communication is primarily computer-mediated and email remains the primary communication medium. As there is no overlap of working hours between the project site in China and the head office in Canada (at least in eastern Canada, where the head office is located), real-time communication media, such as phone conversations and teleconferencing, were not used by the project team, except for very exceptional and/or urgent matters.

The second source of data comprises interviews conducted with key project actors. A total of 20 interviews were carried out with managers of the company and with other project participants. These interviews helped us gain a thorough understanding of various aspects of the project execution process in a construction environment. Face-to-

[1] For reasons of confidentiality, only the author of this report was permitted by the case project provider to access its archived email files.

face discussions complemented the main source of data (email messages) by providing insight into the project from a more global perspective.

3.3 PMBOK® application and database establishment

We used the set of categories by knowledge areas and project management processes defined by the Project Management Institute (PMI, 2004) to examine the information flow patterns and features. Table 3.1 presents the knowledge areas, project management processes and corresponding codes. The definitions provided by the PMI (2004, 2007) for each project management process are included in appendix D.

Table 3.1 Knowledge areas, project management processes and corresponding codes

Knowledge Area	Project Management Process	Code	Knowledge Area	Project Management Process	Code
4. Integration	4.1 Develop Project Charter	P1		10.2 Information Distribution	P30
	4.2 Develop Preliminary Project Scope	P2		10.3 Performance Reporting	P31
	4.3 Develop Project Management Plan	P3		10.4 Manage Stakeholders	P32
	4.4 Direct and Manage Project Execution	P4	11. Risk	11.1 Risk Management Planning	P33
	4.5 Monitor and Control Project Work	P5		11.2 Risk Identification	P34
	4.6 Integrated Change Control	P6		11.3 Qualitative Risk Analysis	P35
	4.7 Close Project	P7		11.4 Quantitative Risk Analysis	P36
5. Scope	5.1 Scope Planning	P8		11.5 Risk Response Planning	P37
	5.2 Scope Definition	P9		11.6 Risk Monitoring and Control	P38
	5.3 Create WBS	P10	12. Procurement	12.1 Plan Purchase and Acquisitions	P39
	5.4 Scope Verification	P11		12.2 Plan Contracting	P40
	5.5 Scope Control	P12		12.3 Request Seller Response	P41
6. Time	6.1 Activity Definition	P13		12.4 Select Sellers	P42
	6.2 Activity Sequencing	P14		12.5 Contract Administration	P43
	6.3 Activity Resource Estimating	P15		12.6 Contract Closure	P44
	6.4 Activity Duration Estimating	P16	13. Safety	13.1 Perform Safety Planning	P45
	6.5 Schedule Development	P17		13.2 Perform Safety Assurance	P46
	6.6 Schedule Control	P18		13.3 Perform Safety Control	P47
7. Cost	7.1 Cost Estimating	P19	14. Environmental	14.1 Perform Environmental Planning	P48
	7.2 Cost Budgeting	P20		14.2 Perform Environmental Assuranc	P49
	7.3 Cost Control	P21		14.3 Perform Environmental Control	P50
8. Quality	8.1 Quality Planning	P22	15. Financial	15.1 Financial Planning	P51
	8.2 Perform Quality Assurance	P23		15.2 Financial Control	P52
	8.3 Perform Quality Control	P24		15.3 Administration and Record	P53
9. Human Resource	9.1 Human Resource Planning	P25	16. Claim	16.1 Claim Identification	P54
	9.2 Acquire Project Team	P26		16.2 Claim Quantification	P55
	9.3 Develop Project Team	P27		16.3 Claim Prevention	P56
	9.4 Manage Project Team	P28		16.4 Claim Resolution	P57
10. Communication	10.1 Communication Planning	P29	17. Others	To be observed	

In *A Guide to the Project Management Body of Knowledge* (*PMBOK® Guide*) (PMI, 2004), the nine knowledge areas are integration, scope, time, cost, quality, HR, communication, risk and procurement. In the *PMBOK® Guide* construction extension (PMI, 2007), the four extended knowledge areas are safety, claims, financial and environmental management.

To examine the characteristics of work activities associated with knowledge areas, if any, that are not included and defined in the *PMBOK® Guide* and the Construction Extension, we created a category named "Others." All the messages related to knowledge areas not defined by the PMI (2004, 2007) were placed in this category for further observation and classification.

To analyze information flows systematically, we reorganized the communication files into 1865 message groups, and classified them into categories that reflect the knowledge areas and project management processes of the *PMBOK® Guide*. The items in the new database include message group serial number, date when the message group was started, topic of the exchanged messages, communication and information dimension, project process category, communication purpose category, sender and receiver of each message, communication purposes, communication loops, and communication duration. The database items are indicated in table 3.2.

The message senders and receivers included all possible project stakeholders in order to observe participation and communication as fully as possible. The communication purposes category includes instruction, request, reporting and notification. The communication loop involves the message-sending action and the action of responding to the message. One communication loop refers to one message sending action and one responding action to the same message. Communication duration refers to the period from the date when the topic started until the closure of the message group.

A few messages exchanged between the iPMO project manager and other project participants concerned how to use emails effectively. One conclusion of this discussion was that only one issue should be addressed per message or message group. However, it was still possible that several topics might be discussed in a single message or message group. We identified the main issue in each message group and categorized the message group into the relevant knowledge area and project process. We codified the message group according to the main topic of the message. This is the same approach applied by Nurmi et al. (2007) in their research.

Table 3.2 Database structure and description

No.	Data categories	Description
1	Serial no.	The unique ID number for each message group
2	Date	Date Ranging from Jan. 1 to Dec. 31, 2005
3	Topic	Examples: Recommended corrective action; Request for information; Change request
4	Project process category	From P1 to P57 Refer to table 3.1 for details
5	Communication purpose category	Instruction Request Reporting Notification
6	Communication loop	One complete communication loop involves one message-sending action and one responding action
7	Communication duration	The period from the date when the topic started until the closure of the discussion
8	Message Sender	CO General Management CO Project Director CO Financial/HR Dept. CO Engineering Dept. CO Shipping/Procurement Dept. CO Suppliers CO Consultant iPMO Project Manager iPMO Supervisor iPMO Administration iPMO Local Customer iPMO Local Contractor iPMO Installer
9	Message Receiver	CO General Management CO Project Director CO Financial/HR Dept. CO Engineering Dept. CO Shipping/Procurement Dept. CO Suppliers CO Consultant iPMO Project Manager iPMO Supervisor iPMO Administration iPMO Local Customer iPMO Local Contractor iPMO Installer

3.4 Modeling technique and Unified Modeling Language (UML)

To improve the project management processes for our case project, or any other project executed in a similar construction environment, we attempted to identify and select the appropriate modeling technique and tool. Various bodies of literature have shown that modeling is a powerful technique that can be applied to address various problems and improve business processes in different industries. In this research, UML was selected as the tool used to define and describe the identified critical construction business processes.

3.4.1 Modeling tool and technique

Modeling depends on the use of the appropriate techniques and tools. In their survey, Davies et al. (2006) found that the six most frequently used modeling techniques are enterprise resourcing (ER) diagrams, data flow diagrams, system flow charts, work flow modeling, UML, and structure charts. The six most widely used modeling tools are Visio, Rational Rose, Oracle9i Developer Suite, iGrafx FlowCharter, AllFusionERwin Data Modeler, and Workflow Modeler.

Of the various modeling techniques, UML is often used to model a broad range of systems and business processes (Wilcox & Gurau, 2003). With the introduction of UML as a formal modeling notation, all project team members are able to gain a global understanding of and a common viewpoint on the project's progress (Eynard, Gallet, Nowak, & Roucoules, 2004). UML is a visual modeling language that has been adopted as a standard for object-oriented modeling and design (Liang, 2003). It describes a system using different levels of abstraction and considering various views. A view is described and formalized by using a number of diagrams with the information focused on a particular aspect of a system (Saleh, 2002).

3.4.2 UML diagrams

UML has 13 diagram types to visualize models and each diagram type describes a projection of a UML model from a specific perspective (Lange, Wijns, & Chaudron, 2007). The advantage of UML is that each diagram can show one aspect of the system and this helps to solve problems with a notation that is intended to cover every aspect of a system. Saleh (2002) summarizes the nine most frequently used UML diagrams:

- Use case diagram: This diagram defines a system's functions and users. Use case is also the starting point for modeling business processes and requirements. The use case notation consists of actors, use cases and associations (Vidgen, 2003). The actors execute use cases, and the associations establish the links between actors and use cases.
- Class diagram: This kind of diagram is used to describe the structure of classes and the possible relationships among them.
- Object diagram: This is a variant of a class diagram and adopts the same notation.
- State chart diagram: This diagram shows the possible behavior of an object using state changes.
- Sequence diagram: This type of diagram describes the interactions between a number of objects in a timeline sequence.
- Collaboration diagram: This diagram shows objects and the messages exchanged between them.
- Activity diagram: This diagram describes a sequential or concurrent flow from one activity to another.
- Component diagram: This kind of diagram defines the physical structure of the code in terms of code components.
- Deployment diagram: This diagram presents the physical architecture and distribution of the hardware and software components in a system.

3.4.3 UML application in construction

As UML is able to describe a system or business process at different levels of abstraction and using different views, it has been used extensively for modeling software systems and business processes. Tsai and Sato (2004) established a UML model to describe an agile production planning and control system. The model is described with a class diagram, whereas sequence diagrams are used to show a job planning and scheduling process in an agile production environment. Their UML-based system can respond immediately to achieve higher service levels, better resource utilization and less material loss. In addition to being applied in an agile production environment, UML can be also used to define and describe various other business processes.

For instance, the research by Wilcox and Gurau (2003) focuses on the identification and analysis of the main advantages of using UML for business modeling. They argue that the development of effective business models can be critical to the understanding and evaluation of a company's procedure. In this regard, they recommend UML as an effective technique for specifying, visualizing, constructing and documenting business models and associated systems. Their UML models specifically address the needs generated by the implementation of customer relationship management in online retailing companies.

UML can also be applied to product life cycle management. The argument made by Thimm, Lee, and Ma (2006) is that product life cycle management requires a modeling framework that indicates the associations among the different life cycle stages, business processes, and stakeholders. UML has good potential to model the product life cycle by enforcing and maintaining model consistency and overcoming various constraints. To illustrate the interest and potential of an object-oriented approach in product data management, Eynard, Gallet, Roucoules, and Ducellier (2006) applied UML to the modeling and integration of product, process and resource data.

UML application has also become an important topic in the construction industry. For instance, Stumf et al. (1996) used UML techniques to build an object-oriented model and provide an integrated information solution for bridging the gap between product and process data in a construction project. For another instance, Fan et al. (2003) developed an object-oriented scheduling model, based on UML, for a construction project. The algorithms they developed can be incorporated into sequencing principles to automatically identify logical sequences with soft logic and encapsulate the concept in a model in an object-oriented paradigm.

The research conducted by Hiremath and Skibniewski (2004) is the best-known work on UML application in the construction industry. By observing a real construction project, Hiremath and Skibniewski (2004) determined that, of all the various information flows in a construction project, only a few have a great impact on the project's cost and progress. The critical information includes requests for information, submittals and change order proposals. The main issue associated with critical information is that there is no well-defined procedure in the construction process to support information flows. To improve construction business processes, the researchers applied use case diagrams, class diagrams, activity diagrams, sequence diagrams, state chart diagrams, and collaboration diagrams to describe the features, procedures and interactions related to a change order proposal evaluation and control. Hiremath and Skibniewski also did a comparative evaluation of traditional structured modeling and modeling by UML for construction processes.

To sum up, UML is a visual modeling language developed and adopted as a standard for object-oriented modeling and design. It is often selected and applied to model a broad range of systems and business processes. UML has 13 diagram types to visualize models. Each diagram type can show one aspect of the system and this helps to solve problems with notation. A review of past research work reveals that various diagrams can also be applied in construction business processes in order to maintain and support information flows.

CHAPTER 4
RESULTS

This chapter presents our results and findings based on the in-depth review and observation of the information flows between project stakeholders in a distributed context. This chapter includes three sections. The first section focuses on the case description. The second section identifies and establishes information flow patterns in the distributed team context. The third section illustrates the identification and analysis of critical construction processes.

4.1 Case description

This section describes the project, the formation and context of the distributed team, and the communication media applied in this construction project. In response to a request for confidentiality by the company, the names of the project and the company studied are not disclosed in this report.

4.1.1 Project description

The case described below was selected as it represents a typical example of a modern construction project in which management and field staff are remote from one another. Engineers, technicians, equipment operators, clerical workers and managers must deal with long distances between the sites, which creates both technical and managerial difficulties.

The company observed in our case is a Canadian firm that provides and installs agricultural turn-key projects on the international market. The project examined for this case study involves the construction of service buildings, greenhouses and equipment, production systems and supporting facilities in northern China. Figure 4.1 shows the bar charts that present the time-phased schedule, at a very high level, for the actual execution of each main project job. It shows that the project preparation work started on December 15, 2004, and construction was ready to start on January 3, 2005.

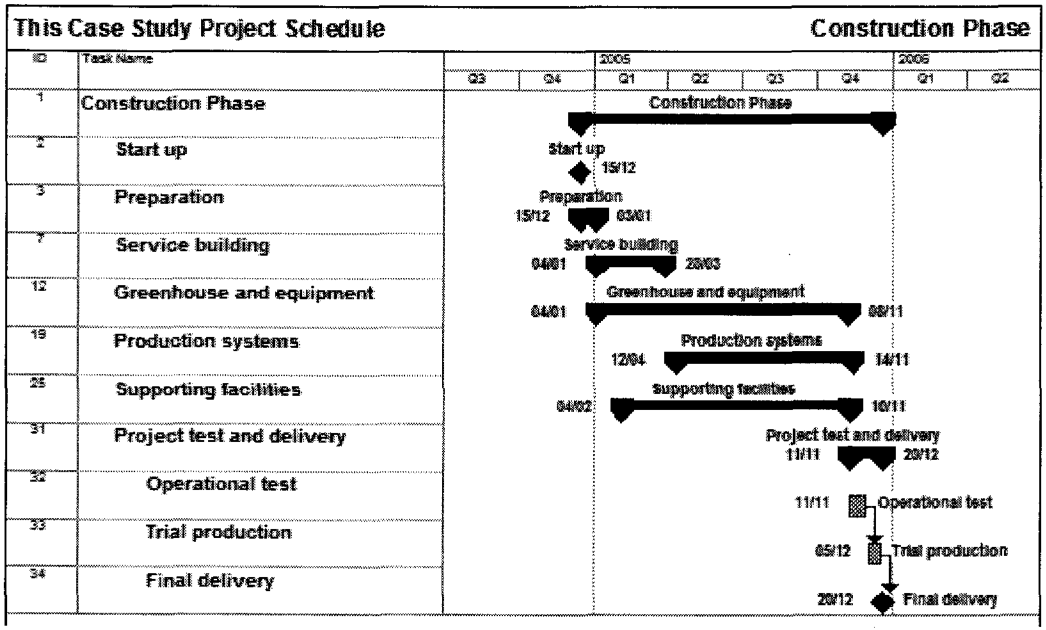

Figure 4.1 The case study project schedule

The construction phase, which covered all physical project work, started on January 4 and finished on December 20, 2005. All of the archived email files for the year 2005, available to this case study, are associated with the information flows among project stakeholders during this phase. This is the phase on which this report focuses. Figure 4.2 shows the facility that the project was set up to build.

Information system applications used for project management in the iPMO were quite limited. Microsoft Office applications were the primary computer-mediated tools applied by the iPMO-based project team. They used Microsoft Project for project planning and progress follow-up and Microsoft Word to create written documents. Microsoft Excel was chosen to carry out the various office work and project administration tasks. The project team used Microsoft Office Outlook as the electronic means for communicating and exchanging messages with the central office in Canada. Documents such as change orders, requests for information, transmittals and submittals were mainly transferred between iPMO and its local stakeholders on paper.

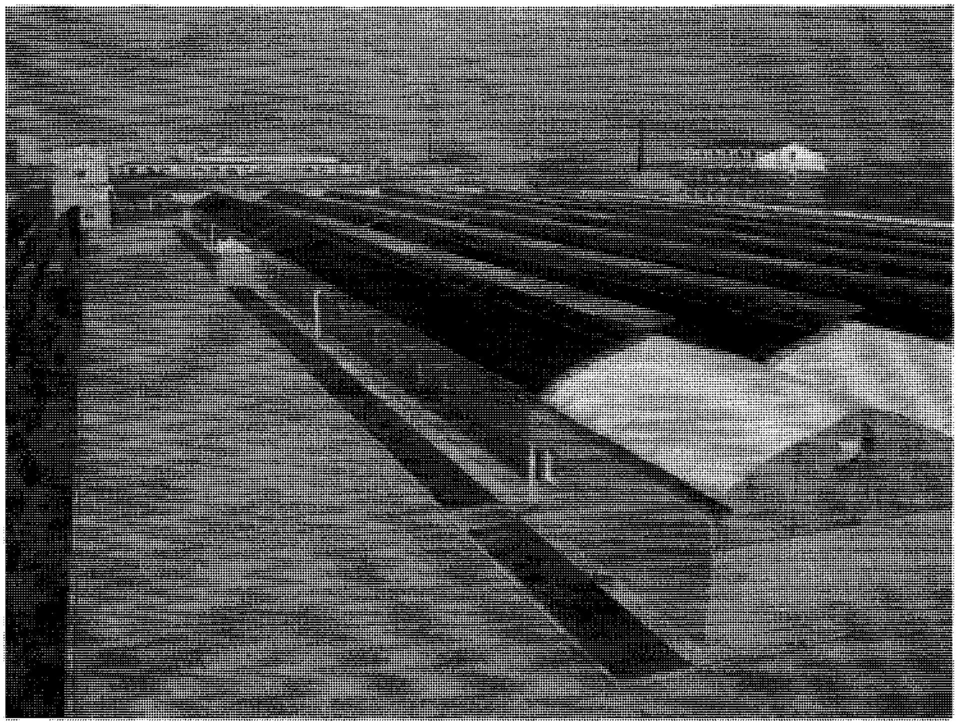

Figure 4.2 Project investigated in this case study

4.1.2 Distributed team formation and context

During the course of the project, most of the management members (general management, project director and various functional departments) were located in Canada. The on-site project management team in China included the construction manager and seven engineers (technical supervisors) who were dispatched from Canada. The locally hired clerical staff of eight at the Chinese office mainly performed the administrative work to support the project's execution and provide services to the people from the Canadian office. Twenty workers (installers) were hired directly by the on-site project office and supervised by the construction manager. About 50 workers from the main contractor were provided to do the various civil engineering and concreting works. Various subcontractors were identified and selected for the specialized outsourcing services needed. Local suppliers were the main source of the materials required for project construction. Figure 4.3 presents the various project stakeholders and the locations where they worked on a daily basis.

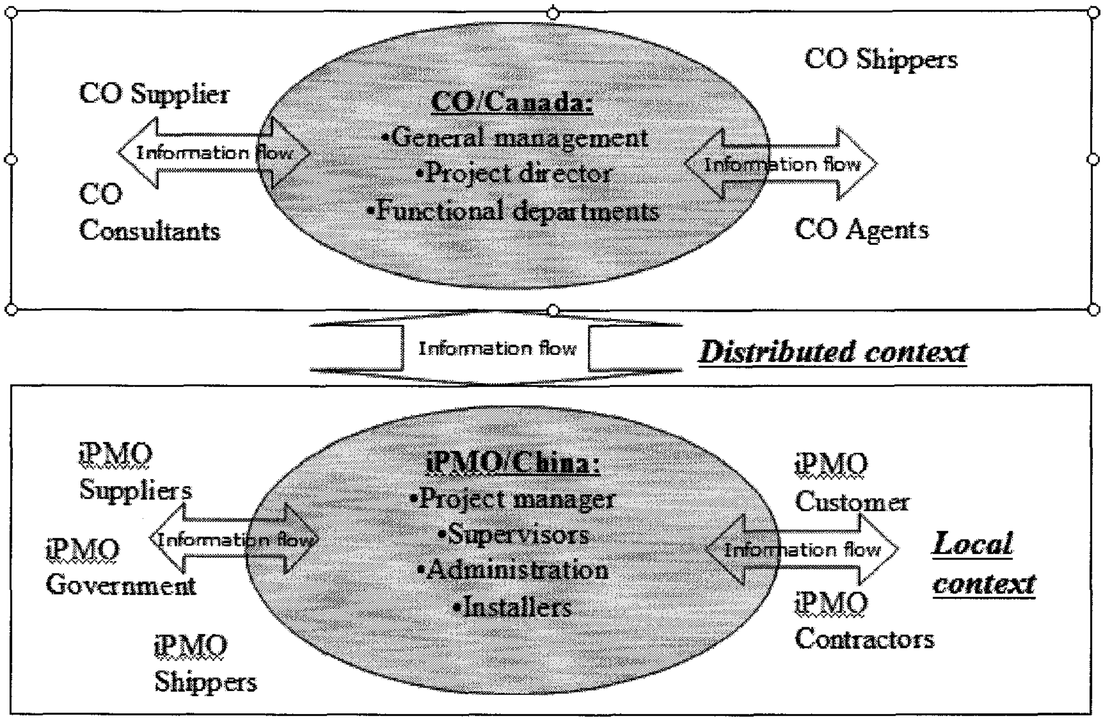

Figure 4.3 Project distributed team context

Table 4.1 summarizes the work locations, roles and main responsibilities of each stakeholder involved in this project. Generally speaking, the mission of the on-site project team was to direct, manage and monitor the project work, and report on the project's progress and status to the central office in Canada. The function of the central office in Canada was to provide the project funding, arrange the required resources, support and supervise the on-site project team, and control the project implementation at a high level. Functioning as a change control board and decision-maker, the central office was also responsible for the integrated change control associated with the project execution.

The on-site iPMO project manager was dispatched to the project site by the central office and anchored there for the whole project construction phase until the end of the project. The iPMO project manager was the principal person in charge of coordination and communication on site. In terms of information flows, the on-site project manager was the key role in the locally based iPMO context.

Table 4.1 Stakeholders' role, work location and main responsibilities

No	Role	Location	Main Responsibilities
1	CO General Management	Canada	Direct high-level project implementation. Serve as change control boards. Maintain appropriate work relations with project client.
2	CO Project Director	Canada	Coordinate project work among various functional departments. Monitor and evaluate on-site project status and progress. Supervise and support the project team on project site.
3	CO Functional Departments	Canada	Prepare and provide project funding. Prepare and provide various resources needed by project. Report to general management and project director at central office.
4	CO Suppliers	Canada	Provide needed services or products to company, as per contract.
5	CO Consultant	Canada	Provide needed services or consultation to company, as per contract.
6	iPMO Project Manager	China	Serve as the key contact for daily communications with central office. Be responsible for overall communications between site office and all project stakeholders. Plan and direct project execution on project site. Coordinate and organize various resources needed on project site.
7	iPMO Supervisor	China	Prepare and plan technical aspects of project work. Monitor and supervise project work executed by installers and local contractors. Report to on-site project manager.
8	iPMO Installers	China	Physically execute construction work.
9	iPMO Administrator	China	Perform various administrative tasks at site office. Report to on-site project manager. Provide services and support to people dispatched from central office.
10	iPMO Project Customer	China	Serve as project owner. Be responsible for project funding. Provide local support services and facilities. Monitor project construction processes. Take over completed project and be responsible for project operation and production.
11	iPMO Contractors	China	Provide needed services or products to on-site project office, as per contract.

The project manager was solely responsible for communications between the iPMO and the central office, and also for information integration and documentation in the local iPMO. Various technical supervisors and engineers from Canada were responsible for the instruction and supervision of the systems installation and operational testing. Installers were hired locally and supervised by the iPMO project manager. The local project-external stakeholders were the project customer (iPMO customer), local contractors (iPMO contractors), local suppliers (iPMO suppliers), local government, and so on.

Table 4.2 compares a few typical features of three different work scenarios and highlights the availability of and limitations on communication media within the distributed project team context in Canada and China. Due to the 12-hour time difference between the project site in China and the head office in Canada, there were no overlapping working hours between the iPMO and the central office. If project stakeholders followed their standard working schedules in their own locations, the whole distributed project team in China and Canada would never have an opportunity for real-time communication and collaboration. This distributed context created a unique challenge in terms of information flows to the project participants in both offices.

Table 4.2 Construction project work context and features

Number	Feature	iPMO and iPMO	iPMO and Local external project stakeholder	iPMO and CO
1	Geography	Co-location	Co-location/Distributed	Distributed
2	Activity boundary	On project site	Domestic, in China	International, across Asia and North America
3	Synchronicity with respect to place	Yes	Dependent upon location of external stakeholder	No
4	Time zone difference	0 hours	0 hours	12 hours
5	Overlapping working hours	100%	100%	0%
6	Synchronicity with respect to time	Yes	Yes	No

4.1.3 Communication media

Three types of communication media were used in this project: traditional, electronic, and connecting. By analyzing communications in this distributed context, we can clearly see the availability of communication media between one project member and another, or between a project member and an external project stakeholder, in different work scenarios. We divided the whole information flow scenario into three categories: within the iPMO, iPMO with local external project stakeholder, and iPMO with CO. The possible communication media include face-to-face meetings, phone, fax, email, online messaging, and teleconferencing/videoconferencing. In the distributed iPMO and CO context, face-to-face meetings, online messaging, and teleconferencing were not possible, as indicated in table 4.3. According to the interview feedback from project participants, phone and fax were rarely used. Only in very urgent situations would people in one place be phoned by people in another place. Fax transmittal was replaced by the combination of email and scanner.

Table 4.3 Availability of communication media in this project context

No.	Communication media	Within iPMO	iPMO with Local outside stakeholder	iPMO with CO
1	Face-to-face meeting	Available	Available	N/A
2	Phone	Available	Available	Rarely used Only for very urgent contacts
3	Fax	Not required	Available	Rarely used Replaced by email + scanner
4	Email	Available	Available	Available
5	Online messaging	Not used	Not used	N/A during working hours
6	Teleconferencing Videoconferencing	Not used	Not used	N/A during working hours

In this distributed iPMO and CO cooperative work context, communication was primarily computer-mediated and email was the primary communication medium. The application and choice of communication media was illustrated by the interview feedback from the project participants. This availability of essentially only one communication medium led to a challenge in terms of information flows to the distributed team. However, the archived message files provide a unique opportunity to access the complete information source for this case study.

Email as a communication medium in our project context was vital to establishing and maintaining high-quality information flows between the distributed iPMO and its central office. In this context, if email transfers did not function or did not function well, information flows could not be exchanged between the distributed project participants. The communication channel across Asia and North America was critical. The notion of time dispersion and the role of time in distributed team communications were vital. The distributed team in this case was a totally asynchronous team that usually had no ability to engage in real-time collaboration.

4.2 Information flow patterns in distributed work

This section focuses on the identification and establishment of information flow patterns associated with the construction project executed in the internationally distributed team context.

4.2.1 Information flow distribution by knowledge area

Knowledge areas, as defined by the PMI (2004), provide a structural framework to visualize information flows from the perspective of communication content. Communication content refers to the information exchanged between the project manager and other project stakeholders during any formal communication and by the use of any medium (Muller 2003). Nurmi et al. (2007) use seven communication content categories to classify and describe the nature of exchanged messages. In their definition, content includes information sharing, task description, feedback, task coordination, rules or norms of cooperation, communication and problems.

In project management practice, communication contents usually refer to the project management knowledge areas defined in the standard *PMBOK® Guide* (PMI, 2004). In the construction industry, Shohet and Frydman (2003) found that the top five communication contents are construction instruction, allocation of manpower, cost control, quality management, and material and equipment. The first four contents are equivalent to the knowledge areas of integration, HR, cost and quality. Material and equipment are not equivalent to a knowledge area defined in the *PMBOK® Guide* or the Construction Extension to the *PMBOK® Guide* (PMI, 2007).

Figure 4.4 shows overall information flow volume distribution by content in each knowledge area category, as identified in the messages. The most important knowledge areas in terms of information flow are communication, integration, procurement, materials and HR. The volume distributions of communication, integration, procurement, materials and HR were 41.1%, 20.1%, 8.7%, 8.6% and 6.4%, respectively.

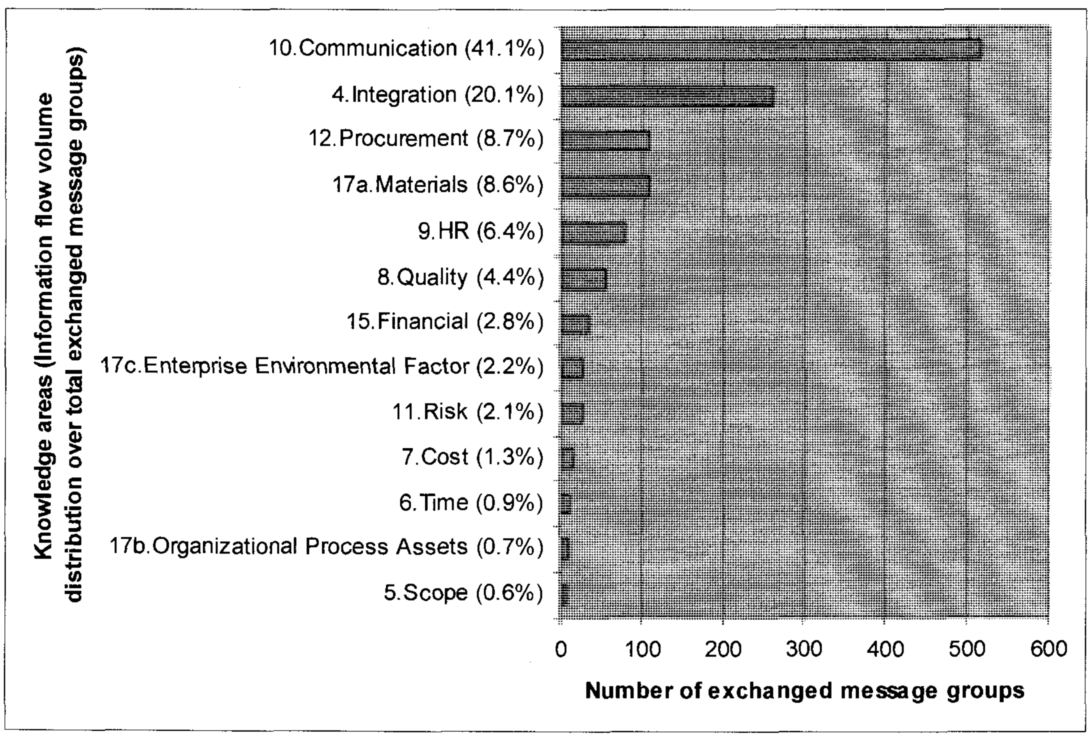

Figure 4.4 Information flows by knowledge area

Similar to the findings of Shohet and Frydman (2003), in the project context we observed, integration, materials and HR were also the three main communication contents between project manager and other project stakeholders. More importantly, our finding confirms that material management is an important work content in construction projects, and it should be included in the next version of Construction Extension to the *PMBOK® Guide*.

Unlike previous researchers, we found that communication is the most important knowledge area in terms of information flow volume distribution. Further to previous researchers' work, we did a detailed breakdown of the message group content for each knowledge area and visualized the project management processes in each area. The results of this breakdown will lay the foundations for understanding the actual business processes and facilitate the formalization of the new construction processes for this project.

4.2.1.1 Information flows in communication

Previous researchers have used different definitions and classifications in the content of communication. Nurmi et al. (2007) defined communication as serving the purpose of social team building. Their communication category includes communications, rules within the team, recording meetings, and testing the visual learning environment tool. The PMI (2004) defines communication as a process through which information is exchanged among persons using a common system of symbols, signs and behaviors. Within this category, communication consists of communication planning, information distribution, performance reporting and stakeholder management. In terms of classification, communication itself, as defined by the PMI (2004), is not emphasized in construction projects according to earlier research (Shohet & Frydman, 2003).

However, as figure 4.4 reveals, we found that 41.1% of all exchanged message groups concerned communication, which makes it the number one content in terms of knowledge area, as measured by information flow volume. Within this knowledge area, as indicated in figure 4.5, information distribution, stakeholder management, and performance reporting account for 80%, 15% and 5%, respectively, of the message groups exchanged. Information distribution dominates information flows within the communication process. The purpose of information distribution is to make necessary information available to project stakeholders in a timely manner.

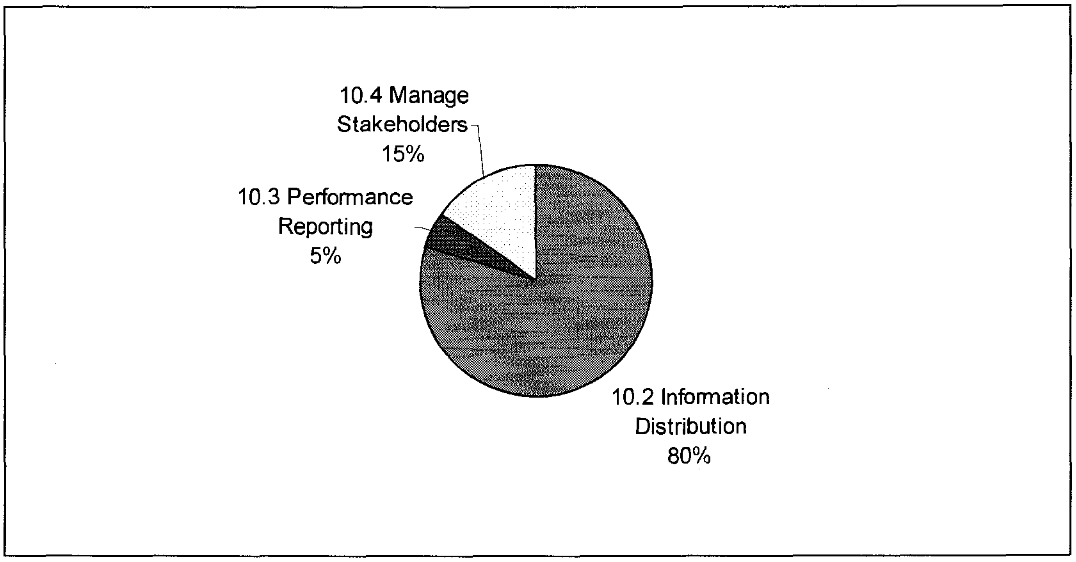

Figure 4.5 Information flows within the communication knowledge area

In a co-located work environment, information distribution might not be a key issue. However, in a distributed team context, information distribution becomes very important. In fact, information distribution represented about 32.8% of all information flows between the on-site project manager and all other stakeholders in the distributed context. This evidence is similar to the findings of Nurmi et al. (2007). In their study, they use "Information Sharing" as one category, parallel to communication, to classify messages that contain very few communicative sentences but mostly represent information that is relevant to other project members. Information sharing is most emphasized in the virtual teamwork context.

Our finding reveals the importance of information distribution between the project manager and other project stakeholders in a distributed construction work environment. This is especially true in a case like this, where the construction activities are organized by the iPMO project manager and executed by the project team in the iPMO. The CO-based project management team needs to be fully informed of the project's physical progress and any other relevant issues. The information distributed is contextual information for the information receivers, and helps them to visualize the project's status.

Stakeholder management is the second most common project process in communication. In the local project context, the important stakeholders included the project customer, local contractors, local suppliers, local government, etc. One key stakeholder was the project customer. Usually, the iPMO project manager was responsible for stakeholder management. To satisfy stakeholders' needs and resolve various issues, especially the project customer, the project manager needed strong support from the central office in Canada.

4.2.1.2 Information flows in integration

As indicated in figure 4.4, integration is the second knowledge area in terms of information flow volume, making up 20.1% of total exchanged message groups between the iPMO project manager and other stakeholders. In the context of managing a project, integration is primarily concerned with effectively integrating the processes that are required to accomplish project objectives within an organization's defined procedure (PMI, 2004). In our case, in sequence, integrated change control accounted for 48% of all integration-related message groups. The second most common project process was project work monitoring and control (24%). As the construction phase observed included the last stage of the project, the volume of information flows on project closure ranked third, accounting for 18% of total integration message groups. The fourth project process was project work execution (10%). Figure 4.6 shows the information flow distribution within the integration knowledge area.

Among the various information flows within a construction project, some may have a higher impact on the project's progress and cost. Hiremath and Skibniewski (2004) found that, in their study, requests for information and change order proposals were the most critical information for the project's implementation. Expediting information flows related to change order proposals and requests for information requires further substantiating documentation. In our case study, the information flows associated with requested changes and requests for information had to consider the time lag across Asia and North America. All requested changes were processed in the integrated change control process, whereas most requests for information concerned project monitoring and project work execution.

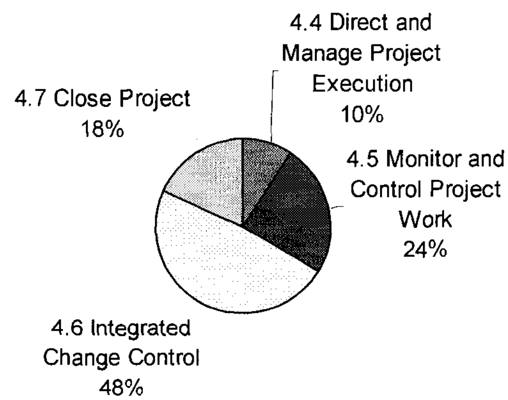

Figure 4.6 Information flows within the integration knowledge area

Change requests and requests for information were usually issued, or reported, by the iPMO project manager, and the request process and evaluation were to be performed by the project management team in the central office. The message delivered and feedback received had to be transferred among the team members using only electronic media. After the request for a change or for information was sent, the project manager had to wait for the response from the central office. The project work depending on the specific answer from the central office was on hold. If this on-hold work was on the project's critical path, any delay in answering by the central office would affect the total length of the project implementation. In such cases, we defined requests for information and requested changes as information critical to the execution of the project. The iPMO project manager and the CO project management team had to pay special attention to this information. The solution was not always for submittals to be planned ahead; rather, how far ahead, in practice, they had to be planned was the issue (Hiremath & Skibniewski, 2004).

4.2.1.3 Information flows in procurement

Project procurement management is a complex process. According to figure 4.4, procurement ranks third and its information flow volume accounts for 8.7% of all exchanged message groups. In this international construction context, some of the products, services or results needed for the whole project came from Canada, and the remainder was procured locally by the iPMO. Most topics related to procurement in the exchanged messages concerned local buying or local orders made by the iPMO. The three most active processes in this knowledge area, as shown in figure 4.7, were requiring seller response (33%), selecting sellers (29%), and contract administration (16%). Purchasing and contracting planning accounted for 11% and 9%, respectively.

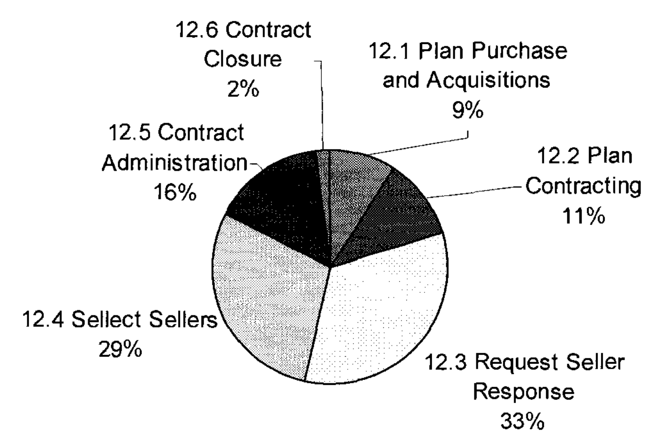

Figure 4.7 Information flows within the procurement knowledge area

Procurement is a management process common to all construction projects. It usually starts with a purchase order that must be filled out by a requester and processed by a purchasing officer. The important tasks include searching the supplier list in the purchasing database, sending emails to qualified suppliers to get quotations, updating the supplier list, ranking the quotations returned, sending the ranked quotations to the requester, deciding on the quotations, placing an order, and updating the order list (Lee & Shi, 2006). Compared with their normal procurement practices, procurement in the locally based iPMO was more complex. Local procurement involved many factors and procedures to be considered and incorporated. Different cultural, social, technical and language environments led to more challenges for the iPMO project team. The procurement management process involves a mutually binding agreement between a seller and a buyer. To complete the agreement successfully, the buyer must first provide sufficient information and documentation to the seller, so that the seller is able to rely upon the information source and understand the requirements in order to establish what the seller is to perform and deliver.

In this distributed project context, the buyer, the iPMO, was unable to initiate the local buying process completely alone. It needed supporting information at the beginning of each local buying process regarding technical specifications, contract statements of work, procurement documentation, and proposal evaluation and screening criteria. At the same time, when the CO made the final decision as to the selection of a local supplier or service provider, the decision-makers there had to rely on the local iPMO to supply further information, such as local resource availability, etc. The iPMO needed to give the CO timely information on the status and progress of each local purchase, and make the right recommendations for the final selection. Effective information flows became a vital factor for the success of each local buying process.

4.2.1.4 Information flows in materials

Materials are vital resources to the effective and efficient execution of a construction project, especially in an international environment. Materials constitute a major portion of a project's total cost and controlling materials is an important subject. The importance of materials management and control has long been established. But in actual practice, materials tracking remains a big problem on job sites today (Navon & Berkovich, 2005). Materials planning, tracking and controlling was also an important project management activity of the project team in our case. According to figure 4.4, topics related to materials and tool management accounted for about 8.6% of the total information flow volume, the same level as procurement management (8.7%).

We classified all the message groups related to materials and determined the categories of the required materials management processes in this environment. Project processes related to materials management in our case project involved materials planning, acquire materials, stock materials, issue materials, materials verification and materials control. For the convenience of observation at a later stage, six materials management processes were defined by extended codes as P58, P59, P60, P61, P62 and P63, respectively. Figure 4.8 illustrates the information flow volume distribution in each materials management process and reveals which ones were most important.

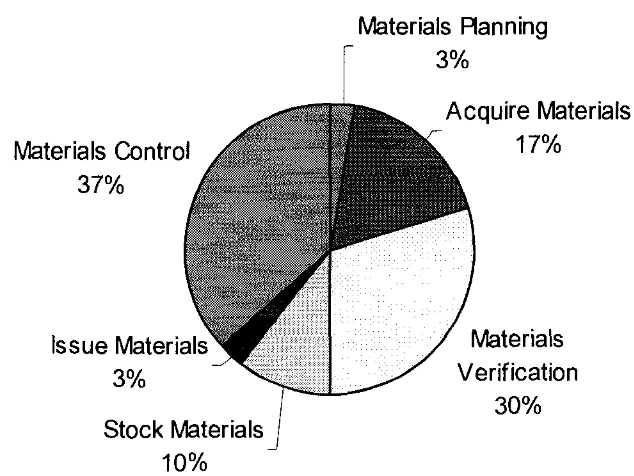

Figure 4.8 Information flows in materials management

This can serve as a pattern of information flows for professionals who are implementing a project in a similar construction environment. More importantly, this evidence reveals the existence and necessity of each materials management process in a construction project environment. The addition of materials as a new knowledge area in the

PMBOK® Guide construction extension would illustrate and clarify the subject of materials management in a construction environment.

4.2.1.5 Information flows in HR

According to figure 4.4, the information flow volume in HR accounts for about 6.4% of total exchanged message groups. Four project management processes in the HR knowledge area were observed in our case study. Since the project was in the construction execution and closure phase, no topics within the information flow message groups concerned HR planning. The main activity in this knowledge area related to managing the project team, which accounted for 61% of the total information flow volume associated with HR activities. The next most important activity in this knowledge area was acquiring the project team, which accounted for 32% of the total HR message groups. The topics related to developing the project team accounted for 4%.

Despite the growing prevalence of distributed teams as a new work form, little is known about the management of virtual/distributed teams and the human resources within them (Hertel, Geister, & Konradt, 2005). In this distributed work context, the project team in the iPMO consisted mainly of two kinds of human resources. The technical supervisors and project managers were dispatched from Canada, where their central office is located, whereas the supporting administration staff members were hired locally. The iPMO project manager exchanged many emails with the central office discussing the issue of acquiring a project team, especially technical supervisors from the CO in Canada.

Human resource availability, travel scheduling, and construction schedule adjustment due to ongoing dynamic changes were a few important factors that could influence the project team acquisition process. When the necessary technical supervisors are working on multiple projects in different places around the world, high-level coordination and communication at the CO is essential to the iPMO. Acquiring the right project team members at the right time is a challenge for the iPMO project manager. Moreover, as the technical supervisors from Canada were usually from a culture and social context very different from the local work and life environment in China, a further challenge for the iPMO was how to help those people to adjust and adapt to local circumstances, and cooperate effectively with various local project stakeholders.

4.2.1.6 Information flows in quality

As shown in figure 4.4, the information flow volume related to quality made up about 4.4% of all exchanged message groups. Quality assurance and control are important processes to ensure that project work is executed to meet requirements and conform to the relevant technical standards and norms. Quality audits and inspections are effective measures to determine whether project work and activities comply with the applicable policies, processes and procedures. To verify and validate the project work done by the iPMO project team and various local parties, independent auditors were required to carry out various inspections over the whole construction life cycle. Using well-trained in-house auditors is generally a good option. The difficulties arise when inspections and audits have to be done in a distributed work context.

The challenge an iPMO often faces is to provide the in-house auditors at the central office with sufficient information on the work for inspection and many other related contextual factors to support the inspection procedure. For example, the result and quality of one project deliverable could be influenced by many factors such as materials use, construction technologies and methods, the installer's experience and skill, the local environment, and so on. Many factors related to the local iPMO project environment are unknown to the quality auditors at the central office. An appropriate flow of information from the iPMO to the CO is critical to the quality audit and inspection process in this distributed work context.

Another challenge an iPMO often faces is local audit and inspection procedures. The local auditors usually have sufficient experience to identify and evaluate various quality problems associated with the local support facilities. However, many imported systems and items of equipment in this particular construction project were very new to the local auditors. When the imported equipment and the local equipment are manufactured according to different quality standards, the local inspection procedure becomes more complicated. An important task for the iPMO project team is to request sufficient information from their CO about the equipment to be inspected and about the technical standards to which the equipment conforms, and to ensure that the local auditors understand all this information.

4.2.1.7 Information flows in finance

According to figure 4.4, the information flow volume in financial management accounts for about 2.8% of all exchanged message groups. Many of the iPMO's daily activities such as local purchase orders and local outsourcing required financial support. The project funds for the iPMO's local activities were provided by the central office. Requesting funds from the CO was an important task for the iPMO project manager. More importantly, the iPMO had to manage financial resources effectively to meet the dynamic funding requirements of various local activities and remain within budget.

Many factors could make the financial management process very difficult. For example, the price of one locally bought material might increase suddenly on the local market, and the budgeted funds were inadequate to cover the new expense. The additional labor used due to project work changes had to be paid for with funds that were not planned for. Local regulations required some specialized equipment for emergency safety procedures that had to be bought and paid for in a very short period. As financial activity in the iPMO was part of the financial management of the whole project at the central office, the provision of local financial information to the CO on a timely basis was crucial.

4.2.1.8 Information flows in enterprise environmental factors

When executing project work during the construction phase, all enterprise environmental factors and organizational process assets that influence the project's success need to be considered. The iPMO in this case was located in China, where the social and cultural context is very different from that in Canada, where the project-performing organization is located. As shown in figure 4.4, the volume of information flows associated with locally based enterprise environmental factors for the iPMO amounted to about 2.2% of the overall information flow volume in this distributed context.

For a project in a very new environment, designers usually do not have direct experience and knowledge of the local circumstances. Many iPMO-based local environment factors cannot be considered and integrated appropriately during the project conception and design phases due to the limited amount of information available. At the beginning of the construction phase in this case, the iPMO project team, especially the members from Canada, had no experience or knowledge of the local environmental factors. They had to take time to understand the local situation and adapt to it.

Local environmental factors involve the local governmental and industry standards, imported materials clearance procedures and permits, local human resources hiring regulations, and local market conditions, etc. In this distributed work context, the CO had to deal with the fact that it did not have information and knowledge of local project environmental factors when it was evaluating the project work and making decisions on issues closely related to the iPMO project context. We observed from the exchanged messages that the iPMO project manager often had to provide information about local environmental factors to the CO.

4.2.1.9 Information flows in risk

As indicated in figure 4.4, about 2.1% of total message groups in this distributed context were related to risk. The international construction environment was totally new to the project team and the organization as a whole. There was a good deal of uncertainty, which could lead to risks for the project implementation. The local contractors might not have adequate skills and capacity to perform a particular construction job. Local inspectors might take much longer than planned to complete inspections and issue their inspection reports. The technical supervisors dispatched did not have permits to do the local specialized work. The dynamic changes during the project execution might cause new risks that could have multiple significant impacts on the project implementation. For example, scope changes approved by the project sponsor or client would cause the iPMO project team to adjust project schedules and reallocate various project resources. However, the required human and material resources might not be available when needed, and the adopted schedule could lead to a late completion date.

4.2.1.10 Information flows in other knowledge areas

We did not find many exchanged messages that addressed topics associated with the remaining knowledge areas such as cost, time and scope. No topics related to safety, environmental or claims management were found in the email message files. But we cannot therefore deduce that no such project activities were carried out. Instead, logically, we can conclude that, even though the iPMO project team involved some or many such activities, they did not need information from the central office to support their local activities.

4.2.1.11 Summary

Based on the identification and classification of the topic and content of each message group, this section establishes the overall information flow patterns between the iPMO project manager and other stakeholders in the distributed context. The evidence reveals that communication, integration, procurement, materials and HR were the most important knowledge areas, from an information flow perspective, to the distributed project team. Further analysis of each knowledge area helps us to understand the actual business processes applied in this distributed work environment. The findings from this section imply that further observation and research efforts should focus on the most important knowledge areas.

4.2.2 Information flow distribution and direction among stakeholders

4.2.2.1 Information flow distribution by volume

No communication or data flows can occur effectively within a project without the support of a proper communication structure. Communication structure is an important research topic in the project management field. Shohet and Frydman (2003) present a "sun-diagram" structure for communication distribution in a construction project environment, with the construction manager located at the center of an interactive communication network. The information from our interviews with the project participants also supports this kind of communication distribution structure in the local iPMO project context, with the iPMO project manager at the center.

In terms of the project manager's role regarding communication, other researchers also confirm that this person is the key contact and all project communication must flow through him or her (Hiremath & Skibniewski, 2004). If the role definition also applies to the project director at the central office, the overall communication distribution structure can be presented as a double sun diagram. This means that all local communication will flow through the iPMO project manager, and all communication at the central office will be channeled to the CO project director. If this is the case, then all information flows over the distributed work context will be conducted between the iPMO project manager and the CO project director. However, our findings do not support this logical assumption. Instead, Figure 4.9 shows the breakdown of communication distribution between the iPMO project manager and the project participants at the central office.

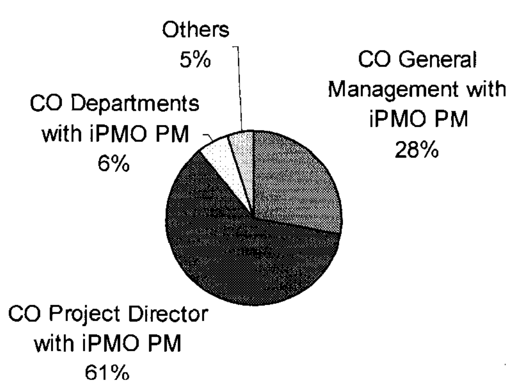

Figure 4.9 Information flow volume for the iPMO project manager by sender and recipient

The distribution reveals that the iPMO project manager devoted more than 60% of his information flows to the project director at the central office, 28% to general management, 6% to various functional departments at the central office, and about 5% to external stakeholders such as consultants, suppliers and transport brokers.

4.2.2.2 Information flows by direction

Figure 4.10 presents the communication and information distribution by direction and volume between the iPMO project manager and project participants at the central office. The information flows between the iPMO project manager and the CO project director moving from the iPMO to the central office represent about 50% of the total information flow volume, and this is the largest information flow channel. Considering that the topics of email messages often concern information distribution, project work information, requests for information and change requests, this channel could be critical to the project work execution by the project team in the iPMO, and clear and complete understanding of project's status by the project principals at the CO.

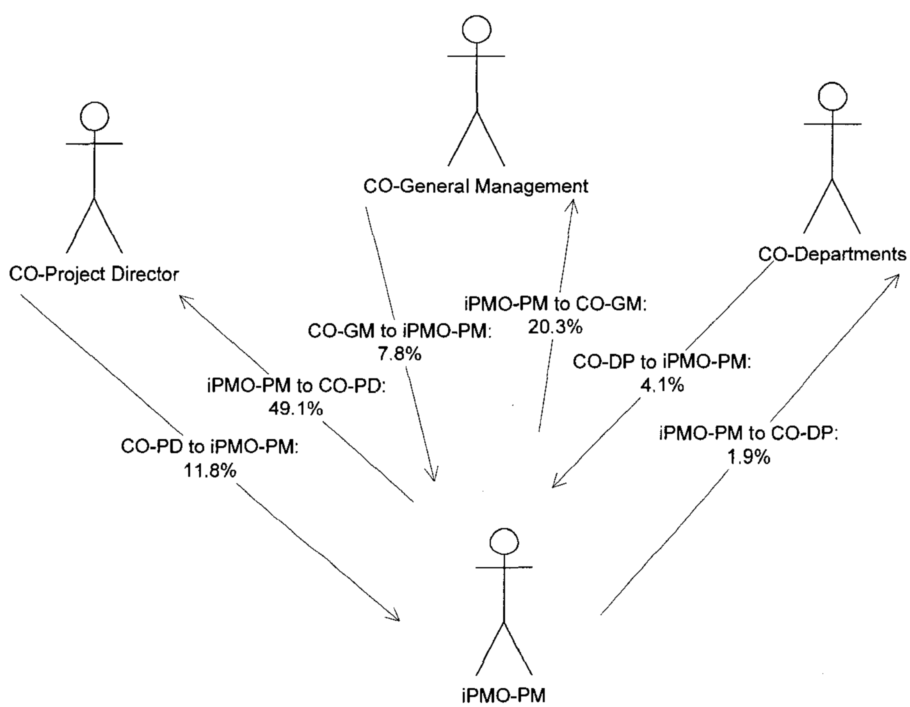

Figure 4.10 Information flow direction and volume between senders and receivers

Measured by the information flow volume, another important communication channel is between the iPMO project manager and general management at the central office, especially moving from the iPMO to the central office. In all the possible channels shown, the information flow is greater from the iPMO to the central office than in the opposite direction. This evidence emphasizes that the iPMO project team was dependent on the central office to supply the necessary information and answers so they could perform the local project work.

Figure 4.11 indicates that the message groups exchanged between the iPMO project manager and the general management at the central office mainly involved topics related to communication, integration, HR, procurement and quality.

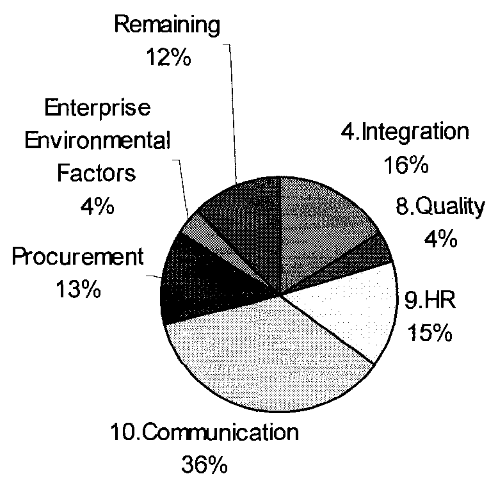

Figure 4.11 Information flows between iPMO-PM and CO-GM

Figure 4.12 shows that the main topics of the messages exchanged between the iPMO project manager and the CO project director are communication, integration, materials, procurement and quality. The two distributions of information flows seem to present very similar patterns over some knowledge areas. For example, communication and integration are the two top knowledge areas in both communication channels. But a further breakdown analysis of the distribution over project manager processes indicates that the contents of the topics in the two communication channels are very different.

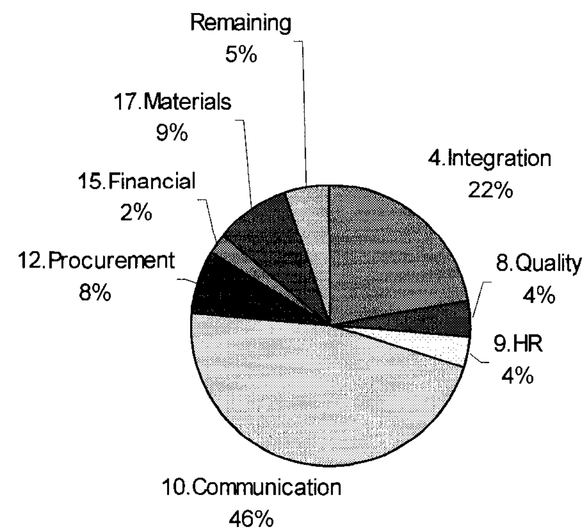

Figure 4.12 Information flows between iPMO PM and CO-PD

4.2.2.3 Project management processes involved

Table 4.4 shows that stakeholder management is the main process in the communication knowledge area discussed within the message groups exchanged between the iPMO project manager and general management at the CO.

Table 4.4 Processes involved between iPMO-PM and CO-GM

No	CO-GM to iPMO-PM	Code	iPMO-PM to CO-GM	Code
1	10.4 Manage Stakeholders	P32	10.4 Manage Stakeholders	P32
2	9.4 Manage Project Team	P28	4.6 Integrated Change Control	P6
3	17b iPMO Process Assets	Others	10.2 Information Distribution	P30
4	4.6 Integrated Change Control	P6	9.4 Manage Project Team	P28
5	8.3 Perform Quality Control	P24	10.3 Performance Reporting	P31

Compared to this, as indicated in table 4.5, the main communication process discussed in messages between the iPMO project manager and the CO project director is information distribution. The other project processes focused on information flows between the iPMO project manager and the CO project director include monitoring and controlling project work, integrated change control, and request seller responses.

Table 4.5 Processes involved between iPMO-PM and CO-PD

No	CO-Project Director to iPMO-PM	Code	iPMO-PM to CO-Project Director	Code
1	4.5 Monitor and Control Project Work	P5	10.2 Information Distribution	P30
2	12.3 Request Seller Response	P41	4.5 Monitor and Control Project Work	P5
3	17.5 Material Controls	P63	4.6 Integrated Change Control	P6
4	4.4 Direct and Manage Project Execution	P4	4.7 Close Project	P7
5	8.2 Perform Quality Assurance	P23	17.5 Material Controls	P63
6	9.4 Manage Project Team	P28	15.2 Financial Control	P52
7	12.4 Select Sellers	P42	17.4 Material Verification	P62
8	17.2 Acquire Materials	P59	10.3 Performance Reporting	P31
9	8.3 Perform Quality Control	P24	8.2 Perform Quality Assurance	P23
10	9.2 Acquire Project Team	P26	12.4 Select Sellers	P42

In addition to the Manage Stakeholder process, the other processes discussed most commonly by the iPMO project manager and general management at the central office are Integrated Change Control and Manage Project Team. This breakdown reveals that the role of the CO project director is mainly to support the iPMO with information flows related to the technical aspects of project work execution and coordination. The information flow topics include requests for missing information on equipment installation and testing, requests for verifying specification information, requested changes to construction procedures and applied technologies, and so on.

The contents of the message groups exchanged between the iPMO project manager and general management at the central office appear to concentrate on the administrative aspects of the support and instruction of the local project work. For example, a scope change from the project customer would require a very high-level discussion and coordination for evaluation and approval. Discussions directly between the iPMO project manager and general management at the central office were more effective and efficient.

4.2.2.4 Summary

The evidence from the observations in this section reveal that internal information flows inside the project company in this distributed context remain dominant. The iPMO project manager devoted more than 60% of his information flow efforts to the project director at the central office, and 28% to general management. The internal information flow volume accounts for about 95% of all message groups exchanged. Only about 5% is associated with information flows with the external stakeholders. This finding implies that archived messages files are a good information source for observation and studies for the purpose of identifying issues associated with internal business processes in this distributed work environment and proposing appropriate solutions.

4.3 Identification and analysis of critical construction processes

4.3.1 Classification according to information flow purpose

The preceding sections mainly observed information flow patterns by measuring the volume distribution over different knowledge areas and project management processes. Volume distribution in a management process may reflect the extent to which the iPMO project team depends on the central office, or vice versa, in terms of information flow needs within the distributed work context, to perform the project work related to the given process.

However, that kind of observation does not reveal many details concerning the nature of the topic itself within the messages. This section will constitute an in-depth study of the exchanged message groups in order to classify and differentiate the nature of the information flows. When we determined the purpose of each message group, we found that all messages can be classified into two main categories: communication and information requests, and information sharing. The communication and information request category includes instructions, requests and ad hoc reporting. The information sharing category contains notification and routine reports.

Figure 4.13 presents a generic information flow model in this internationally distributed work context. Notification and routine reporting usually occur when a project task is finished, whereas instruction, requests and ad hoc reporting can happen at any time over the whole life cycle of the project work. For example, the iPMO project manager might ask the central office to provide missing information on a planned construction job, make a change request if a different procedure or different material had to be used, and call for a quality review when the system was installed.

This generic information flow highlights the necessity of information as an essential input to the project work execution in the iPMO. The more interactive features of information flows in the instruction, request and ad hoc reporting categories, between the iPMO project manager and other project stakeholders at the central office imply that the messages in such categories are more likely to address various issues. This assumption is justified and supported based on the detailed review and observation of the email communication process in this distributed context.

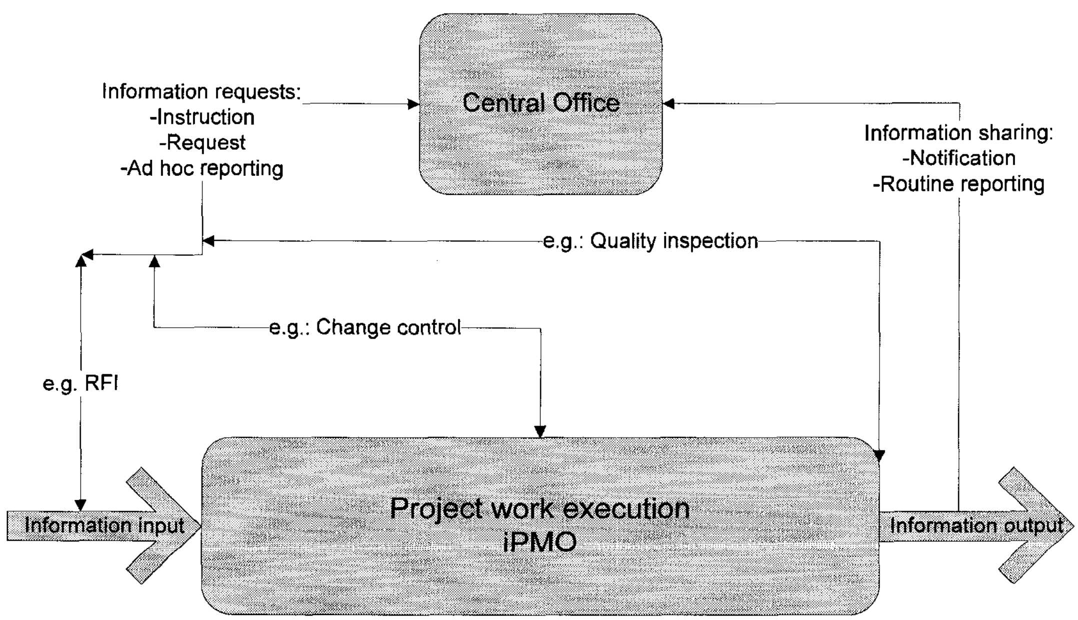

Figure 4.13 Generic information flow model within the distributed context

Figure 4.14 shows the distribution of message groups among the different categories. Routine reporting ranks first among five categories observed and makes up 37% of all message groups. The next category is ad hoc reporting, which accounts for 32% of all message groups. Requests constitute the third category and their volume of messages is 16%. Instruction and notification are at a similar level, and account for 7% and 8%, respectively, of all message groups.

The message groups in the notification and routine reporting categories usually do not contain any communicative issues or subjects. For the purpose of identifying issues, these message groups need not be focused on further in our research effort. The information inside such message groups is often delivered on a regular basis, such as every week, every two weeks, every month and so on. The real purpose of such message groups is to keep the recipients informed. This is essential to the project principals at the central office so they can better understand the project status on site. For example, the iPMO project manager sent a large amount of project information such as pictures and project performance information so that the project participants at the central office would understand the project's progress on the project site.

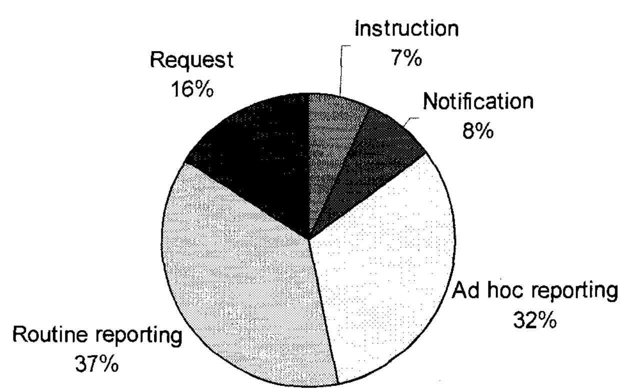

Figure 4.14 Classification by message purpose

Figure 4.15 further illustrates the non-communicative nature of the message groups in the categories of notification and routine reporting. This feature is specifically measured by communication loops. As stated in chapter 3, one communication loop involves one message-sending action and one action responding to the same message. If the communication loop index is 0.5, it means that the message receiver does not respond to the sender. The evidence shows that, in the categories of notification and routine reporting, the message senders mostly do not get a response from the recipients. Even when the recipients respond, they usually merely inform the senders that the message has been received. In such a case, the communication is complete in a single loop. For example, the financial department at the central office advised the iPMO project manager that the approved funds had been transferred from the CO to the local iPMO bank account. The iPMO project manager would probably reply to the message to inform the financial department that the transferred funds had been received.

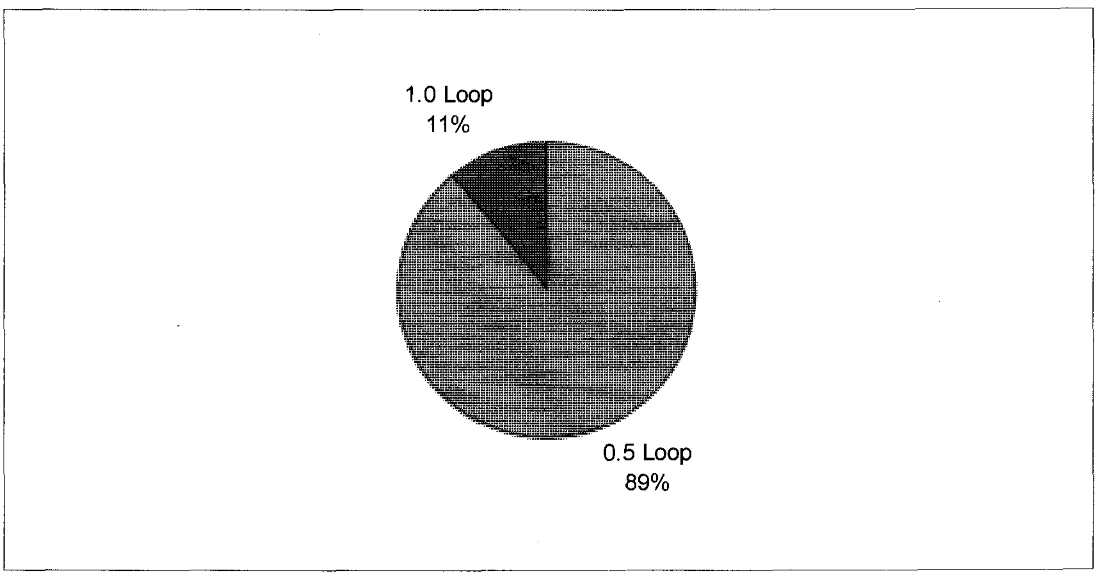

Figure 4.15 Message groups within the notification and routine reporting categories

Compared to the messages within the notification and routine reporting categories, the message groups inside the instruction, request and ad hoc reporting categories are more communicative about a range of questions and issues. As any discussion of questions or issues in a distributed context will involve at least one communication loop, we need to pay special attention to those messages as they may reflect the essential problems associated with the project management processes. Figure 4.16 presents the information flow volume distribution over different communication loops between the message senders and recipients. Topics that could be completed within one communication loop make up 66% of all message groups in these categories. For example, the iPMO project team found that the technical specifications on the installation of one imported system were missing, and the project manager sent a request for information to the project director at the central office. Next morning, he received the requested information from the project director and the topic was completed and closed within one communication loop.

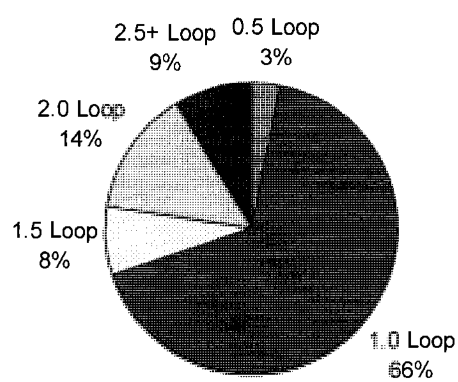

Figure 4.16 Message groups within the instruction, ad hoc reporting and request categories

However, open topics may sometimes need more communication loops to discuss an issue, find a solution or make a decision. According to figure 4.16, topics closed within 1.5 loops, 2.0 loops and more than 2.0 loops account for 8%, 14% and 9%, respectively. More than 30% of the message groups could not be completed within one communication loop. We can again consider the above example to illustrate a situation when more communication would be required. The iPMO project manager found that the model and product serial number in the newly received information from the central office did not match the numbers on the actual system received. In such a case, the project manager had to request the right information again or to find out whether the instructions might still correspond to the actual system received on site. Before receiving the correct information from the central office, the project team in the iPMO could not install the system. If the team got the right answer or the missing information from the next message from the central office, the open issue was closed. Otherwise, the team had to continue the communication.

The message groups inside the instruction, request and ad hoc reporting categories have a common feature: their topics involve questions that have to be answered, or issues that must be resolved, within this distributed work context. Such message groups contain more communicative contents that need more interactive communication and discussion between project participants. The real purpose of such message groups is communication and information requests. Our findings in this case study emphasize that information is a necessary resource and input to perform any project work. When the iPMO has sufficient and appropriate information, the project team there does not need information flows with the central office.

4.3.2 Information flows by duration and number of loops

Figure 4.17 shows that the message groups related to information sharing and completed in 0.5 loops mainly fall within the communication knowledge area. The dominant processes in this knowledge area are information distribution and performance reporting. Other knowledge areas that possess some information sharing messages are integration and finance. As stated above, such message groups do not contain real communicative questions or issues. Those messages were transferred by email as there was no other communication medium or information system that the project team could use in this distributed work context.

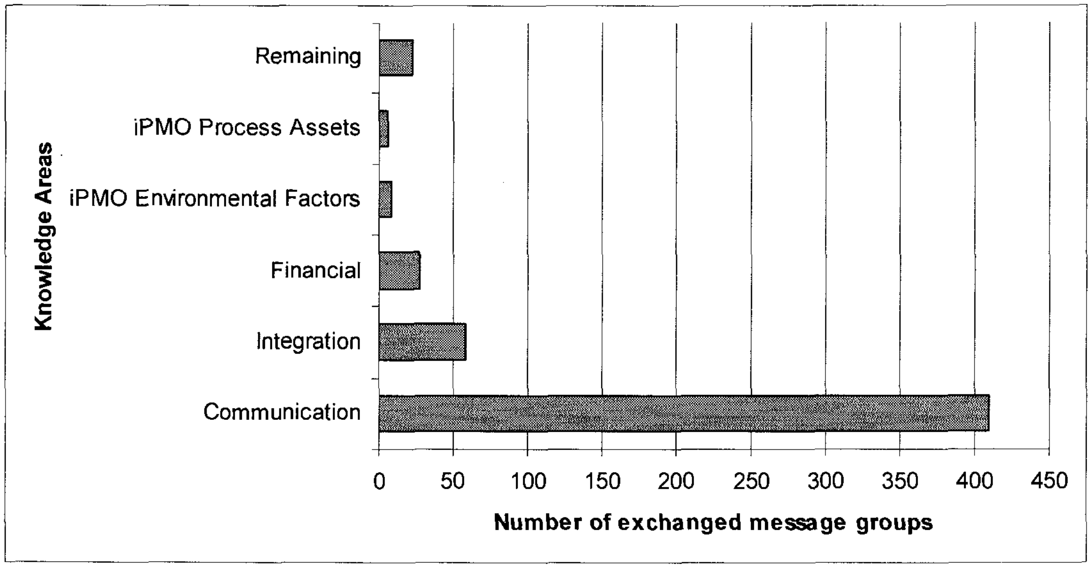

Figure 4.17 Information flows over 0.5 communication loops

When such messages, usually with a large document attached, are sent to one participant and copied to all other relevant participants, the messages would take up too much storage space on each recipient's computer. If the sender only sends the message to one recipient, the person who receives the message has to download the information and place it on a platform that everyone could access. This operation by the recipient means double work or rework, which does not add value to the project. Since this situation could be improved by using an appropriate information system, the identification and selection of an appropriate project management information system (PMIS) to address the need for information in this kind of distributed work context is essential. However, PMIS selection is not within the scope of this research.

As the message groups with more than one communication loop usually contained real communicative questions and issues, we made a breakdown and established the information flow distribution patterns over various knowledge areas, as shown in figure 4.18.

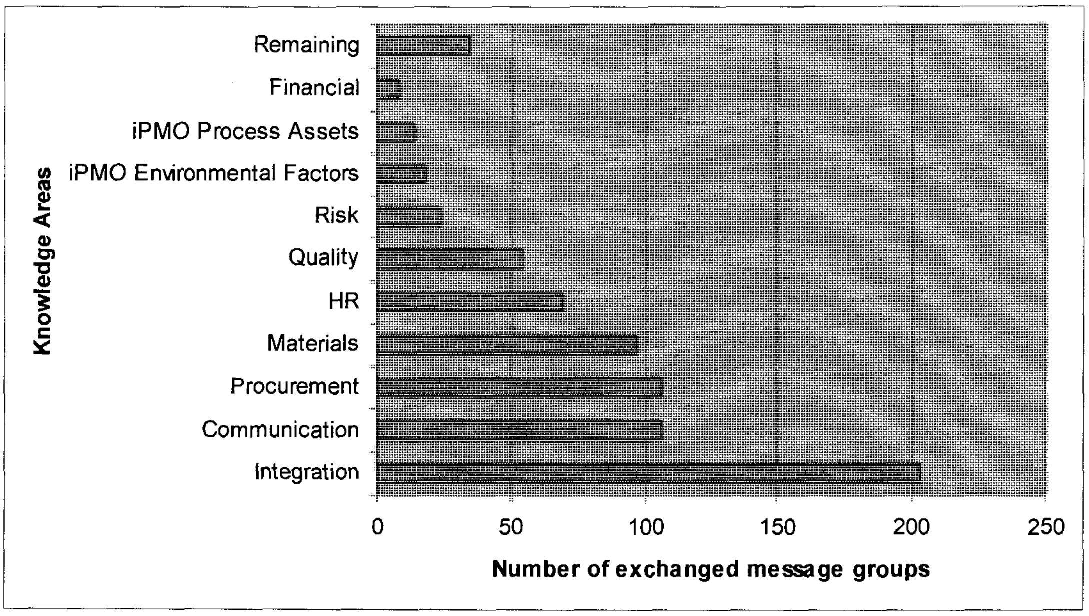

Figure 4.18 Information flows over 1.0 or more than 1.0 communication loops

Integration, communication, procurement, materials, and HR are the five most important knowledge areas that may contain a large amount of communicative questions or issues to be responded to. Given that there is no overlap of working hours in this distributed work context, the most efficient option was for communication between senders and recipients to be completed and closed within 24 hours and in one communication loop. As we observed, problematic issues could take more time and more communication loops to be solved. We can identify the knowledge areas and project processes that required more exchanged messages lasting over 24 hours and involving more than one communication loop.

Figure 4.19 shows the information flow distribution patterns of messages that lasted over 24 hours and occupied more than one communication loop. It reveals that integration, procurement and materials are the top three areas containing these kinds of exchanged messages. In the following section, we will focus on the communicative questions or issues related to various processes associated with integration, procurement and materials.

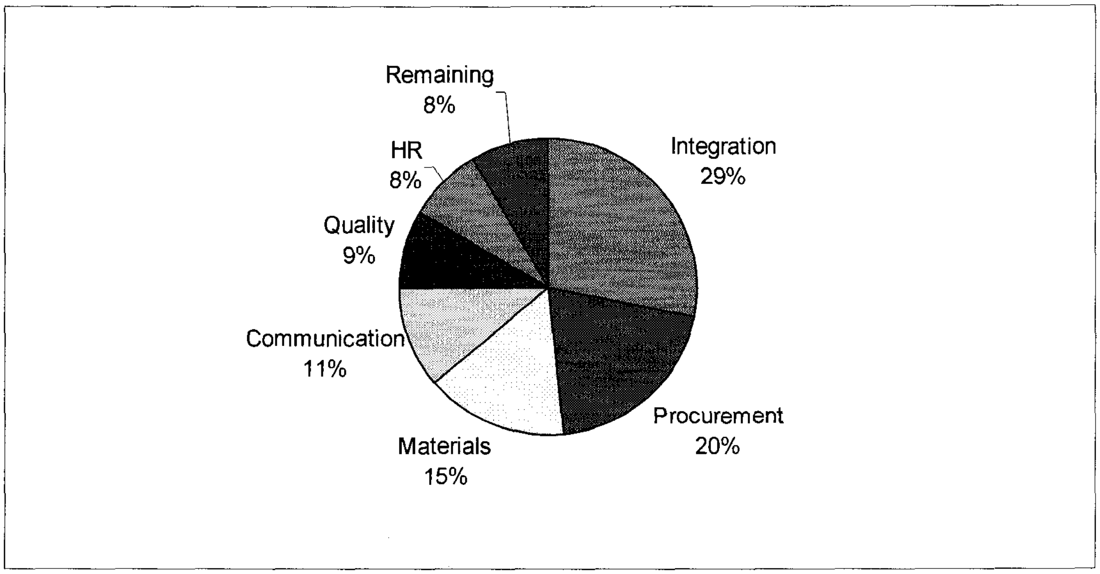

Figure 4.19 Information flows over more than 1.0 communication loop and two or more days

4.3.3 Issue identification and observation in selected areas

The first section of this chapter identified communication, integration, procurement, materials and HR as the most important knowledge areas involved in this distributed project context. Further observation of the interactive features of information flows reveals that integration, procurement and materials are the three areas in which there are the most communicative questions and issues. The project management processes associated with integration, procurement and materials are most critical to project execution in this distributed work context. Based on the findings presented in previous sections, this section mainly concerns the identification and classification of various issues affecting integration, procurement and materials.

4.3.3.1 Integration

The Canadian firm that allowed us to study this project has more than fifteen years of experience with similar construction projects on the world market. However, iPMO project teams working on its various projects do not have well-defined working processes or procedures for different management processes. Our previous observations of information flow patterns in integration revealed that the process groups involved in this project during the construction phase, according to the conceptual framework defined by the PMBOK®, mainly include Direct and Manage Project Execution, Monitor and Control Project Work, Integrated Change Control, and Close Project.

In reality, the company will require a more practical process that reflects the nature of the construction industry. Based on our discussions with the project participants, we found that the most practical processes mainly involve Prepare and Instruct Project Work, Execute and Verify Project Work, Document and Report Project Work, Change Order and Control, Do Operational Testing, and Deliver and Close Project.

Further interviews and discussions with the project participants revealed that there are no well-defined subprocesses related to working procedures and role definition and responsibility. It is often not clear to project participants, especially new members, who should do what work when, what kind of information will be needed for the work, and from whom they can obtain the information they need. More importantly, project participants do not know whether and what issues exist in the integration work for construction. Direct observation of the contents of exchanged email messages will be essential in order to understand the nature of the issues associated with construction integration.

The common issue in the Prepare and Instruct subprocess was that the iPMO project team did not know whether they had the appropriate information to instruct the installers and execute the project work. Different situations might arise, causing the same problem. For instance, the iPMO might simply not have the necessary information because it did not have the complete technical drawings. Or the iPMO might have the information, but in fact the information was not correct because the drawing had not been updated, and the information on the old version was outdated. Furthermore, due to lack of information transfer tracking and documentation, the iPMO project team did not know whether information on the version of the document they had was correct or not. Having the appropriate information was essential to the iPMO technical supervisor in order to prepare for the planned work and train the installers correctly. Project participants mentioned that training the installers properly is very important to achieve high-quality work. In one real example, the project team faced a very serious quality issue because the installers were not well trained at the beginning of the work. A complete list of issues identified related to integration appears in Appendix A.

One issue in the Execute and Verify subprocess is that executed or planned work would be on hold or pending as the iPMO had to contact the CO and request the needed information. As the project team usually only knew that the information they needed was not available, they had to stop the work and wait for instructions or an answer from the central office. The situation was much worse if the CO did not have the requested information and had to contact the supplier that provided the materials or equipment. Another issue the iPMO faced was doing the wrong work because they had relied on the wrong instructions and did not know this in advance.

The analysis of the content of exchanged messages in integration reveals that the distributed project team faced numerous issues related to change orders and control. The sources of change requests included the local project client, the contractor and subcontractors, and the iPMO project team. One root cause of the change requests was that the designs in the drawings did not fit the local project needs. The local construction procedures and materials application also led to a range of changes to the preplanned construction procedure or technology.

The central office had its own difficulties when dealing with change requests. Project participants at the CO mentioned a few times that they did not remember certain change requests and their outcomes, and they could not find the files or records to keep the information in the change requests. They also mentioned in various messages that they were not always able to evaluate change requests, because they did not have enough information to understand the request and make the right decision in a timely manner. When they did not understand the subject, they had to contact the iPMO and request more information or clarify certain details that they were confused about. In this distributed work context, such communication and discussions are really time-consuming, as communication loops could not be completed in one day. When the iPMO was waiting for the result of the change request evaluation to proceed with the planned work, or continue their work, they faced more problems in dealing with the issues related to the pending work.

The iPMO's objective in the Document and Report subprocess was to provide the central office with the information it needed to evaluate the project work. However, the CO mentioned in various messages that project participants there did not have enough information to analyze the project work because the iPMO had failed to send it. When information flows are not well documented, a project team in this kind of distributed context will face more challenges at the final stage of construction. In the Deliver and Close subprocess, one important task for the distributed team is to provide the as-built document to the local project owner. Usually this paperwork is completed by the project participants at the central office. During this final stage, many discussions are conducted between the project participants in the distributed team. The purpose of this kind of interaction is to assemble the as-built information. As the iPMO did not keep such information on hand, it had to check the actual work executed on site to get it.

In conclusion, the various identified issues reflect the following common problems in integration management:

- Lack of well-defined subprocesses and procedures.
- Lack of well-defined roles and responsibilities.
- Lack of well-defined information needs and communication instructions.
- Lack of understanding of issues associated with the subprocesses.

These problems must be resolved in order to successfully manage project integration.

4.3.3.2 Procurement

As defined by the PMI (2004), procurement management includes six subprocesses: plan purchasing and acquisitions, plan contracting, request seller response, select sellers, contract administration and contract closure. In general, this framework can also serve as a guideline applying to procurement management in this case study. However, further observations and interviews with the project stakeholders revealed that a framework adapted to the actual construction process, based on the best practices used by the company studied, would be more applicable and practical. The adapted framework consists of five subprocesses: Prepare Purchase Order (PO), Request for Proposals, Select Suppliers, PO Administration and Follow-up, and Order Delivery and Reception.

In each procurement subprocess, we identified various issues on the basis of the messages exchanged by the distributed team. A complete list of issues related to procurement is presented in Appendix B. Most of the identified issues are associated with the subprocesses at the beginning stages of procurement. More than 50% of the identified issues relate to the Prepare PO and Request for Proposal subprocesses. For instance, the iPMO intended to search for a local option to replace imported equipment, but it did not have clear specifications for the equipment to be sought out. Thus, the iPMO needed to contact its central office to obtain the information. If the iPMO did not need to handle this subject urgently, the project participants could take their time in communicating. However, if the iPMO did not use well-defined specifications to place the order, it could face more serious consequences. One real example was when a required component was not installed on a piece of locally ordered equipment due to confusion concerning the order requirements and specifications.

Further evidence related to this issue from the exchanged messages includes:

- CO asked for a local option material, but did not provide clear specifications.
- iPMO received a request from CO to search for a product, but there was no information on technical capacity.
- CO asked iPMO to search locally for a piece of equipment. But iPMO was not clear about many details of the requirements and specifications.
- A new material was required due to a change; it was too expensive to send it from CO; iPMO wanted to check local options but they did not know the requirements and specifications. They also did not know the local market conditions and local suppliers.

Another issue identified from the exchanged messages is that there was confusion concerning communication procedures across different procurement subprocesses. The evidence from the messages includes:

- iPMO had to confirm an order with a local supplier the next day, but the technical capacity had not yet been concluded with CO. iPMO sent a message requesting confirmation, but CO forgot to answer.
- The requirements for some equipment were not well defined. iPMO had a few meetings and discussions about the proposal. Finally, this equipment was removed from the project scope.
- iPMO asked a local supplier to provide a proposal, while at the same time CO and iPMO were discussing an important data point for the specifications.
- Technical questions were still under discussion between iPMO and CO when a PO was confirmed with a local supplier.
- The price for an outsourcing service was not clear and iPMO found it too expensive when the service provider executed the work.
- A confirmed PO with a local supplier could not be executed due to incorrect pricing information on the contract.
- iPMO found out that a locally made option was not applicable only after completing the procedure. It had to rethink the two options: one via PO and another one locally made.

As in the previous section, various identified issues related to procurement reflect the following common problems in procurement management:

- Lack of well-defined subprocesses and procedures.
- Lack of well-defined roles and responsibilities.
- Lack of well-defined information needs and communication instructions.
- Lack of understanding of issues associated with the subprocesses.

These problems must be resolved in order to successfully manage project procurement.

4.3.3.3 Materials

As illustrated in the first section of this chapter, our findings reveal the existence and necessity of the following six materials subprocesses: Materials Planning, Acquire Materials, Stock Materials, Issue Materials, Materials Verification and Materials Control. We did an in-depth investigation of the exchanged message groups related to materials. A complete list of identified issues related to materials is presented in Appendix C.

A project executed in an international construction environment represents a challenge for the project team when it comes to materials planning. The two different sources of materials create more uncertainties for the project team managing the materials. The issues related to materials planning include:

- An important piece of equipment was not available when it was needed for the project work.
- A locally sourced material was not included in the materials planning; iPMO asked CO to send it while it was already doing the job.
- Another imported material was required due to a change; it was only by chance that the material received was adequate to cover the need.
- In one case, there were only enough imported materials to complete part of the planning work; the size of the materials received did not fit with local needs; there was no link between materials used and materials in inventory.
- In another case, there were not enough imported materials to complete the planning work. iPMO only found this out when executing the planning work, and work was held up while they waited for more materials to be delivered.

One common issue the iPMO faced was that the instructions for the materials, especially imported ones, were missing. The evidence includes:

- iPMO requested instructions on how to assemble some materials; CO said they had provided them; planning work was on hold for this reason.

- iPMO did not have the instructions for an item of imported equipment; CO had no information on one locally used material.
- iPMO received imported material from CO, but did not know where to install it; there were no instructions to follow.
- iPMO found that imported materials were not available when they executed the work. iPMO checked with CO, which answered that the materials had been delivered a long time before. The materials were missing and there were no records to track.

Lack of materials flow documentation is also a common issue that the distributed team faced in different subprocesses, from Acquire Materials, to Stock Materials, to Issue Materials. The evidence from the exchanged messages includes:

- CO asked whether the site inventory had a certain list of materials; iPMO had to physically check the inventory to find the answer.
- CO did not have clear information on the materials stocked on the project site; iPMO had to check the inventory and find the materials to determine the answer.
- A requested change involved a change of material uses; the delivered materials for this project were installed. At the end, iPMO found two leftovers from the inventory for the other project, but no specification information.
- iPMO could not find any information on one material in the files.

The lack of any link between the materials used in the project work and materials planned or prepared for was a difficulty the iPMO faced often. The evidence concerning this issue includes:

- A piece of equipment needed to be assembled with received materials, but there were no information and instructions on this matter; iPMO was not clear on how much material would be required to complete various work using the same kinds of materials.

- It was not clear to iPMO whether certain planned work would be done using imported materials; iPMO and CO had a different understanding of the timing of the work.
- The quantity and size of the received materials did not fit the needs for the planned work. There was no clear connection between the materials received and the project work. Missing or wrong materials were only identified when the work was being done.

As in the previous sections, various identified issues related to materials also reflect the following common problems in materials management:

- Lack of well-defined subprocesses and procedures.
- Lack of well-defined roles and responsibilities.
- Lack of well-defined information needs and communication instructions.
- Lack of understanding of issues associated with the subprocesses.

These problems must be resolved in order to successfully manage project materials.

4.3.4 Summary

The first section of this chapter established the information flow patterns for all knowledge areas involved and determined that the most important knowledge areas in this distributed context are communication, integration, procurement, materials and HR. The second section further observed the interactive information flow features of the exchanged message groups and revealed that integration, procurement and materials are the three areas affected by the most communicative questions and issues. The project management processes that are associated with integration, procurement and materials are most critical to the execution of the project in this distributed context.

The third section mainly focused on the identification and classification of various issues affecting integration, procurement and materials. Three complete lists of issues identified for integration, procurement and materials appear in Appendices A, B and C, respectively. More importantly, the evidence reveals that the common problems in all these areas are a lack of well-defined subprocesses and procedures, a lack of well-defined roles and responsibilities, a lack of well-defined information needs and communication instructions, and a lack of understanding of issues associated with the subprocesses.

Finding and proposing appropriate solutions to address the identified issues and resolve the common problems will be the most important research objective discussed in the next chapter.

CHAPTER 5

DISCUSSION, ANALYSIS AND PROPOSED SOLUTIONS

Now that the various issues and common problems related to integration, procurement and materials have been investigated, identified and documented in the previous chapter, this chapter focuses on identifying and proposing appropriate solutions by addressing these issues and problems.

5.1 Integration

This section discusses the use of a generic integration model, use case model, and various activity diagram models in order to resolve the identified issues and common problems.

5.1.1 Generic integration model

As illustrated in the previous chapter, an integration management framework based on the best practices from the company studied includes the following subprocesses: Start Up, Prepare and Instruct Project Work, Execute and Verify Project Work, Document and Report Project Work, Change Order and Control, Do Operational Testing, and Deliver and Close Project. In practice, any project work in the subprocesses of Prepare and Instruct Project Work, Execute and Verify Project Work, and Do Operational Testing may involve requested changes related to the Change Order and Control subprocess, which is performed while those three subprocesses are being executed.

Figure 5.1 depicts a generic integration model that presents the subprocesses related to integration management. As indicated in the figure, the generic integration model is established on the basis of three main information sources. The first source is interviews and discussions with the project stakeholders. The second is the literature, especially the PMI's (2004) PMBOK®. The third is the observation of the information flows between stakeholders in this distributed work context. This generic model clearly shows the sequences and relationships among the various subprocesses related to integration management. The project team will perform those subprocesses and procedures proposed in the generic integration model in order to execute each project work related to integration. When a project work starts, project team in iPMO needs to make the necessary preparation and give the instruction to the installers who physically execute the planned work. When the work is executed actually, the verification will be essential in order to ensure that the work execution is done according to the established requirements, defined procedure and related norms or standards. As the project key actors are working in an international distributed context, project work documentation and reporting in an effective manner will be crucial to the project team in iPMO.

When all project works are accomplished, the important task for the project team in iPMO is to do the operational testing. One of the key objectives of operational testing is the complete integration of the various test requirements for the overall project. Each system will be evaluated in terms of technical performance, functional effectiveness and integrative compatibility. In this subprocess, the introduction of a change will likely affect many different components of a tested system or many different aspects of the overall project. It is very important that all the change requests are evaluated and processed appropriately. As the change control board for this case project is located in central office in Canada, project team in iPMO needs to perform the respective procedures more effectively in order to facilitate the change control board in central office to make the right judgment and decisions.

The last subprocess in the proposed generic integration model is Deliver and Close Project. This subprocess closes out the portions of the project scope and associated activities applicable to the construction phase. This subprocess also establishes the procedures to integrate and coordinate necessary activities to verify and document the project deliverables, and to interact and formalize the acceptances of those accomplished deliverables by the project customer.

Although this generic model clearly presents the sequences and relationships among the various subprocesses related to integration management, it does not provide a detailed solution to address common problems or individual identified issues. The next section focuses on the application of UML techniques and the development of more detailed models to resolve such problems and issues.

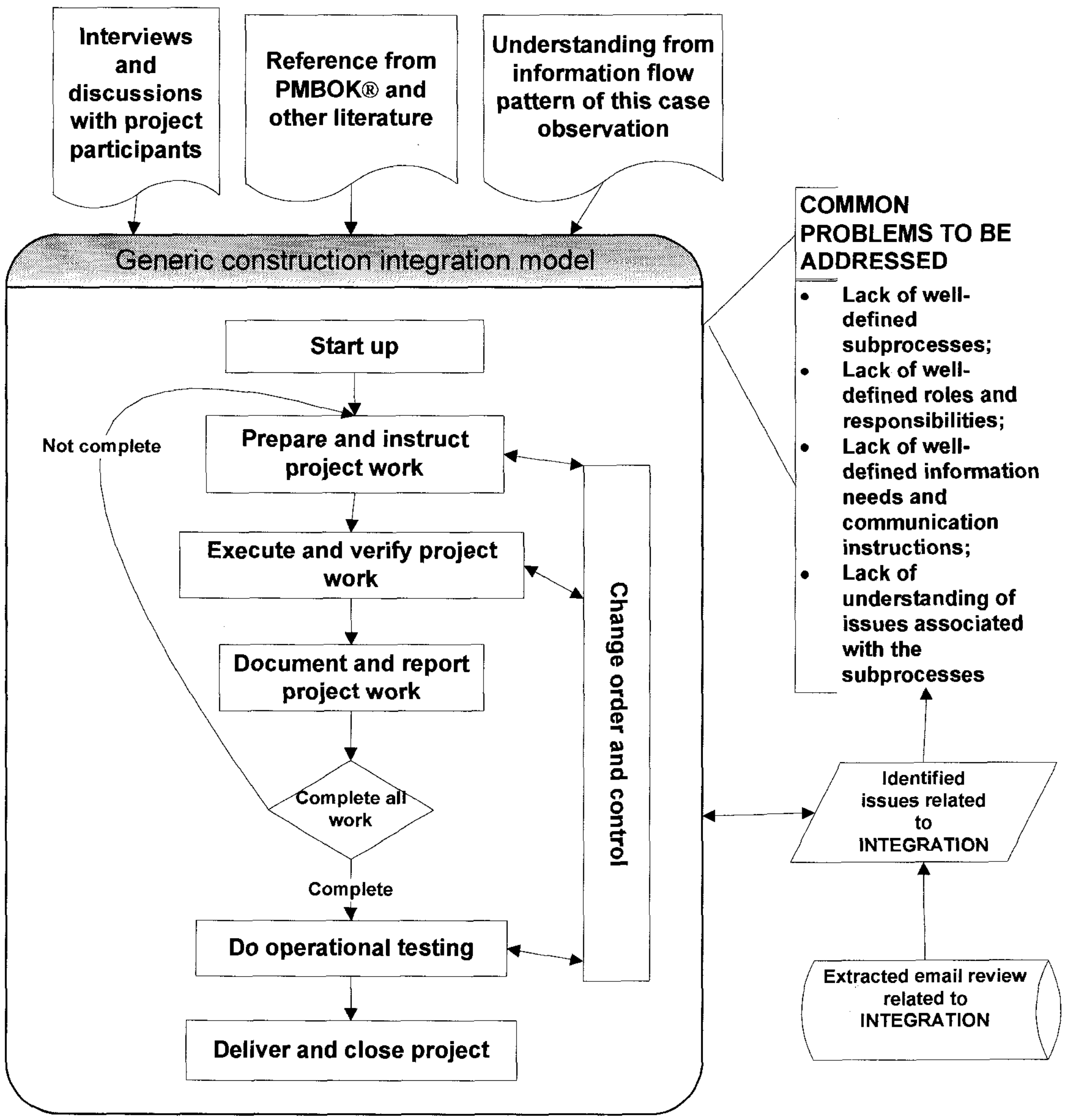

Figure 5.1 Generic integration model

5.1.2 Use case model

One important function of any use case model is to define roles and the corresponding responsibilities. As shown in figure 5.2, in this case, the key stakeholders were the iPMO project manager, the iPMO technical supervisor, the iPMO installer, project owner or customer, local inspector, and the CO in Canada. The complete model involves all the subprocesses: Start Up, Prepare and Instruct Project Work, Execute and Verify Project Work, Document and Report Project Work, Change Order and Control, Do Operational Testing, and Deliver and Close Project.[2]

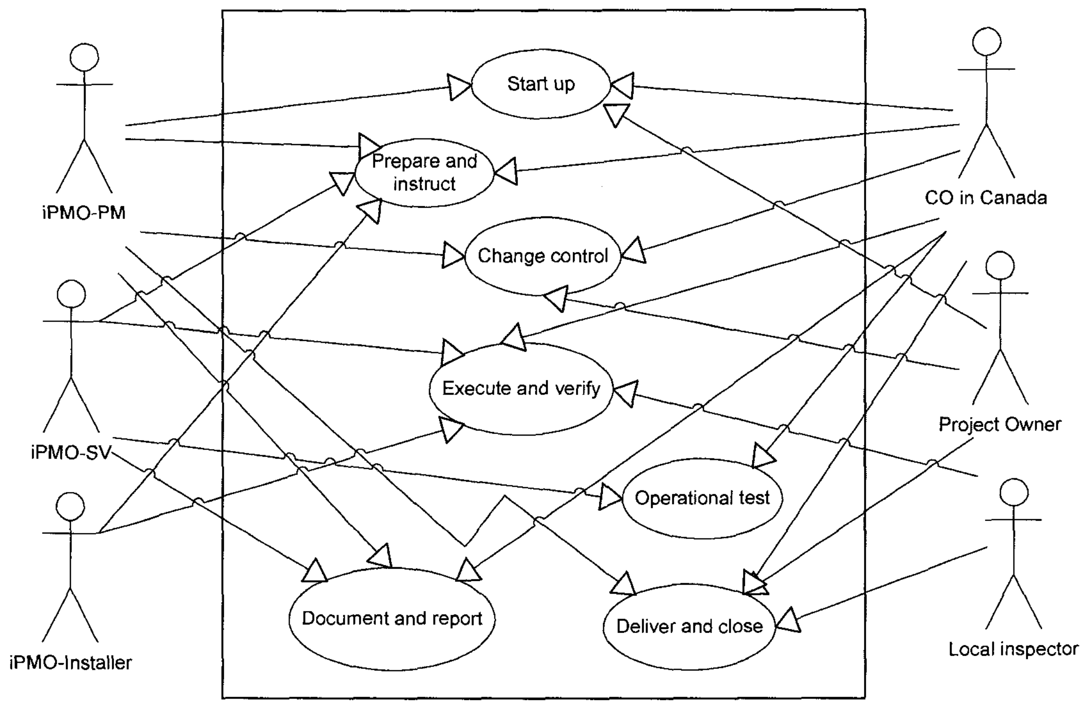

Figure 5.2 Use case diagram for integration

5.1.3 Activity diagrams for integration

5.1.3.1 Start up

At the start-up stage, the key stakeholders are the iPMO project manager, the local project owner, and the CO in Canada.

[2] To keep the text inside figure 5.2 simple, the names of the subprocesses are abbreviated.

5.1.3.2 Prepare and instruct project work

The main identified issues related to integration involve the lack of proper preparation for instruction documents and information, the lack of adequate training of the installers, and the lack of reviews and checks of the availability of various required resources. Accordingly, at the Prepare and Instruct stage, the main tasks for the project team were to ensure that all the necessary components for executing the installation work were available and ready, and to make sure the installers understood the technical procedures and requirements for the installation.

The two principal types of documents to check and follow were the project schedule and technical drawings. The project schedule gave the project team the specific timing information about when the project work would be performed and what the relationship was between this work and the preceding and following jobs. Sometimes the project schedule did not contain details on the project task, and the project team had to further break down and divide the work package into executable activities, so that they could be assigned to the various installers at the same time. The project team needed to pay attention to the influence of the planned work installation on any changes in the project scope. If a change of project scope could not be avoided, the project team had to check with their change control boards at the central office for further evaluation and approval. Figure 5.3 presents this subprocess in detail.

Technical drawings are critical documents for a team executing a project in the construction industry. The distributed work environment in this case project highlighted the importance of high-quality technical drawings. However, as the technical drawings were designed and created by the designers at the central office, many elements and details were not applicable to the local iPMO situation. For example, one system that worked perfectly in a previously built project was unable to function well in the new project location. Design feasibility and system adaptation to the local circumstances were important tasks for the project team. Interfaces between imported equipment and

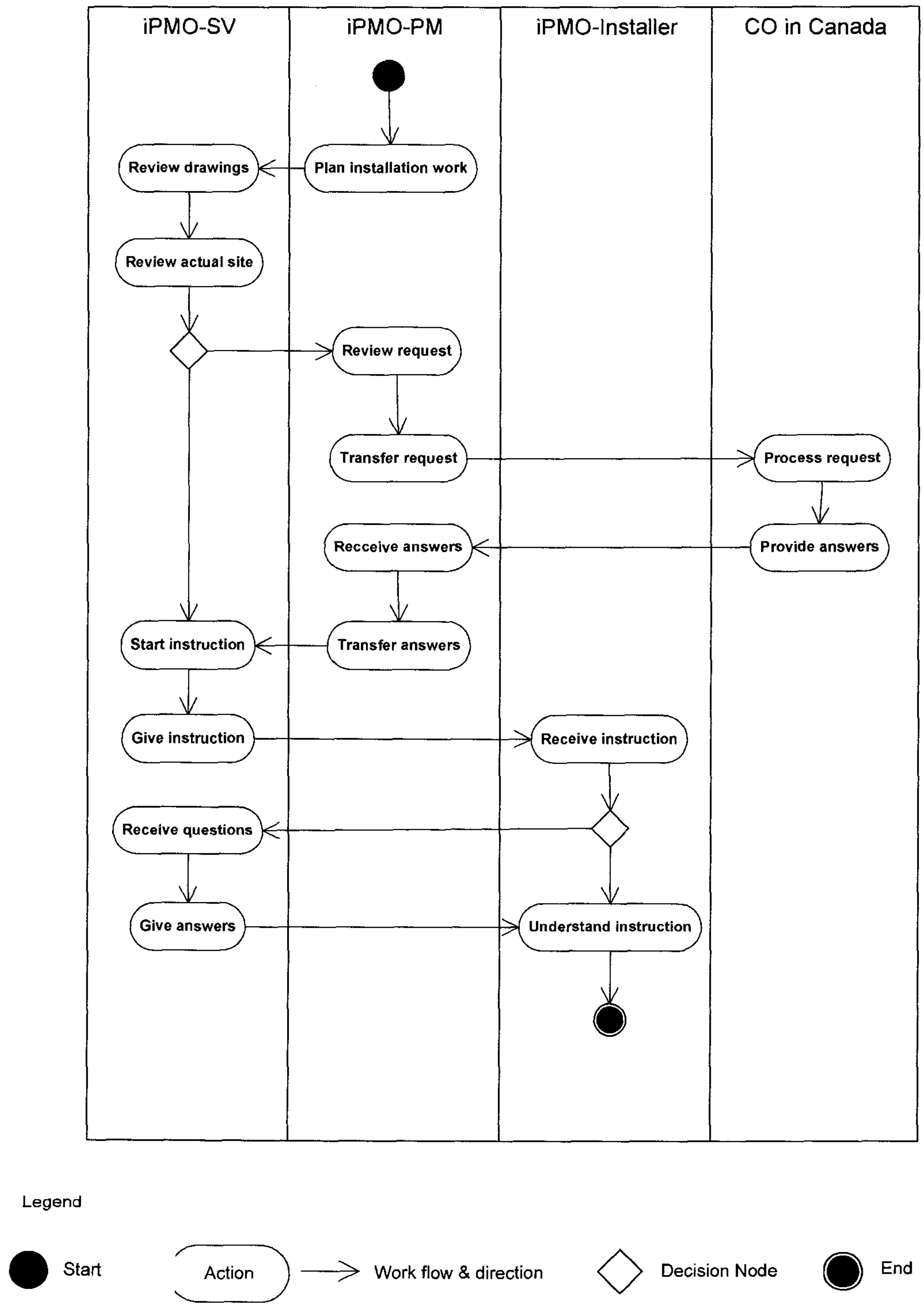

Figure 5.3 Prepare and instruct project work

the local system network often became problematic. When the project team reviewed the technical drawings to plan the project work, they had to be careful about potential problem areas derived from the application of different systems, principles, technical norms and construction procedures and requirements. When they found a conflict or unsuitable design in the drawings, they needed to raise the issue and request a change or recommend corrective action to their change control boards at the CO.

One actual problem from the case study was that the project team often found that instructions were missing or did not fit the actual situation only when they were executing the project work. In such cases, the iPMO had to stop the project work and wait for information from the CO. When such situations occurred, they had a very negative impact on the project work execution at the iPMO. To avoid this negative situation, the proposed model includes a review of drawings and a check of the actual situation as important tasks at this stage, and clarifies that this is the responsibility of the technical supervisors.

Resource availability is another important component that a project team should check very carefully when planning project work. In this particular project, the iPMO had its own team of technical installers. The project team at the iPMO did not face difficulties when using their own installers on the project work they were planning. When the installers were from outside, however, a project team may run more risk of not getting the installers when they are needed. The iPMO project manager has to negotiate and maintain installer availability with the supplier of installers. Installation tools could become a restrictive component if the project team fails to manage them well. As specialized heavy installation equipment is usually rented from a local source where the iPMO is located, safety requirements and procedures are key issues. Another essential resource is material for the execution of the planning work. As mentioned previously, when materials are imported from a country other than the one where the iPMO is located, the project team should double-check the suitability of the materials in the local application. If the materials are from local suppliers or the local market, the project team should focus on their quality and technical performance. Such materials availability checks may lead to change requests, recommended corrective actions or recommended preventive actions. In such cases, the project team needs to address these issues with the change control boards. As one issue identified is that major rework can be caused by the use of low-quality materials, a materials check at this stage should also include a quality verification.

As installation work is performed physically by different installers, appropriate training is critical to high-quality results. As mentioned above, using poorly trained installers is an important factor causing major rework problems. An essential task for the project team in the iPMO, especially the technical supervisors, is to train and instruct the installers very well, so they are able to understand the technology associated with the installation work. When the installers have no experience with installing similar projects, training and instruction can be a challenging task. A good practice from this case project was that the iPMO hired and kept its own installers with the specialized skills required to execute the project work properly. However, the iPMO had to pay special attention to training installers from external HR resources. To assure proper training, the proposed model recommends that the technical supervisors should provide interactive instructions for the installers.

5.1.3.3 Execute and verify project work

One main issue identified in the Execute and Verify subprocess was that the executed work would be on hold because the iPMO had to ask the CO for the information it needed. Another key issue that the iPMO faced was doing the wrong work because it had applied the wrong instructions and did not know this in advance. About 24% of observed message groups are related to these two main issues.[3] However, these two issues could have been largely avoided at this stage if the project team had done their work properly at the Prepare and Instruct stage, as indicated in figure 5.4.

The other issues identified also involve the importance of work verification and quality assurance. Accordingly, an essential task at this stage is to verify the results of the

[3] These two issues are addressed in the message groups numbered 6, 10, 15, 17, 25, 26, 27, 31, 34, 40, 45, 51, 52, 55 and 57 in Appendix A.

project work completed by the installers and perform a quality audit. Failure to meet the quality standards could easily lead to much higher costs when the consequences of a problem influence the whole system's operations and corrective action has to be taken at the operation phase.

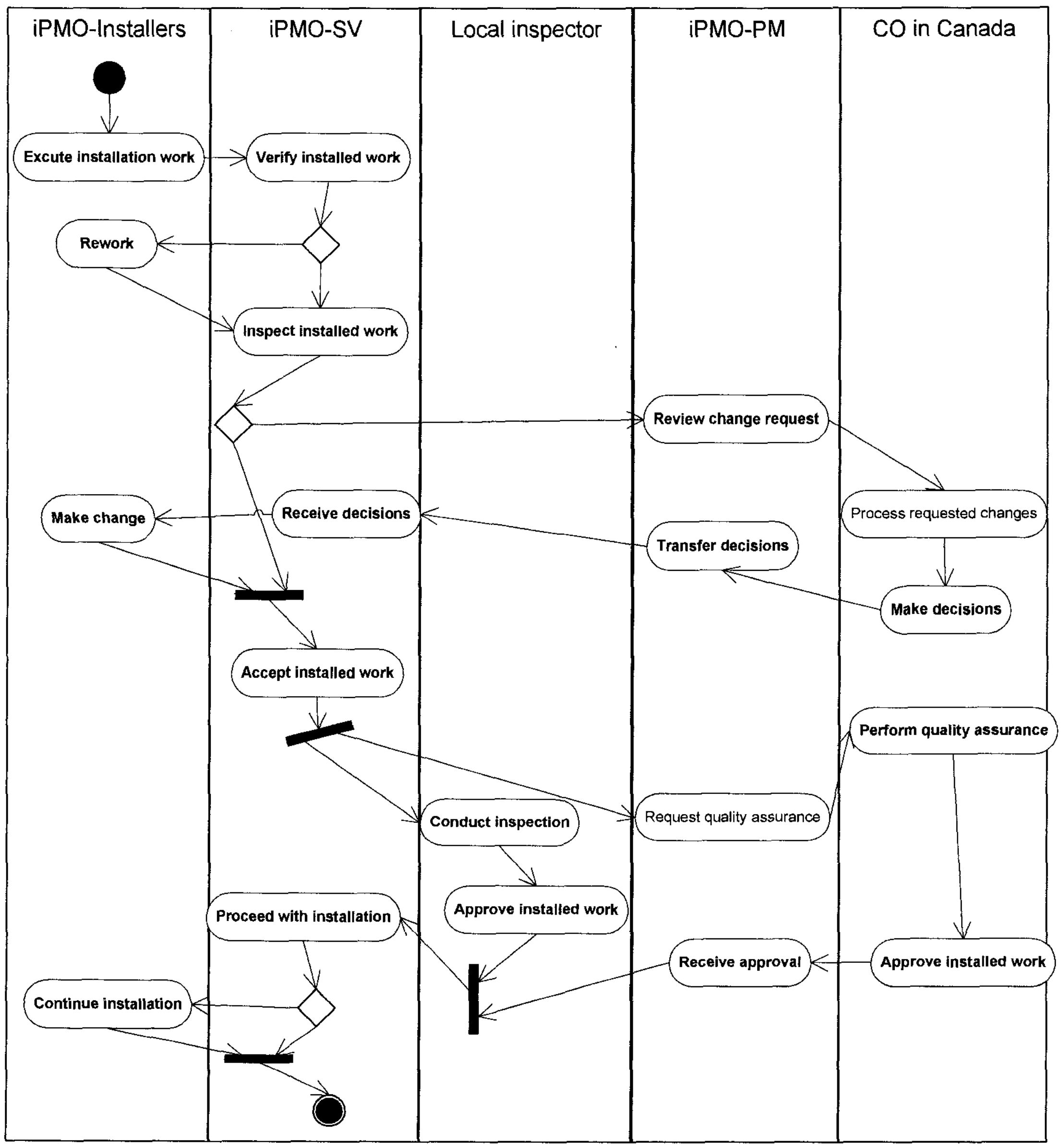

Figure 5.4 Execute and verify project work

Again, well-trained installers are the most significant factor of the inputs contributing to high-quality project work. It may not be easy for technical supervisors, acting as the internal quality inspectors, to detect problems if the project work is not performed properly by the installers. A simple example from our case was connecting the roof gutters on the greenhouse columns using nuts and bolts. Unless the inspectors checked each connection in person, they did not know whether the bolts were tightened appropriately.

Using well-trained installers for these kinds of work could avoid many problems. This is one important lesson we learned from the case project. The technical supervisors on site at an iPMO are the people responsible for high-quality project work. To assure the quality of the installation, properly trained in-house auditors from the central office need to come to the project site at regular intervals. This usually constitutes an independent quality audit to determine whether the project work complies with the technical norms, processes and procedures of the project-performing organization.

Among the issues identified, two major problems that had occurred in previous projects also happened in this one. This suggests that an iPMO, and especially its technical supervisors, should check the lessons-learned database when inspecting installed work. If the technical supervisors had checked the lessons-learned database, they would have noticed that the installed work had a major defect. The iPMO needed to make a change request, recommending corrective action. When the central office reviewed and approved the requested change, a corrective action would be implemented immediately.

When a project is executed in an international environment, the iPMO project team often faces the issue of applying different specification standards. In this case, all the equipment installed on the project site had to comply with all relevant technical standards and norms applicable in China. In this case, even well-trained in-house quality auditors were not able to inspect the installation's quality according to local quality standards. The solution was to identify and arrange for a local inspector to conduct an official, independent audit. This kind of scheduled quality review by local quality inspectors results in valuable documentation and certificates that will be needed for the final acceptance of the project.

Sometimes the technical supervisors in an the iPMO cannot find defects by themselves. In such cases, the defects, if any, are usually identified and pointed out by the independent quality inspectors or auditors during the quality inspection. Those defects should also be well documented and reported to the change control boards at the central office for further evaluation and review.

During the quality review and check by the internal and external inspectors, corrective and preventive measures are also important in improving and maintaining high-quality installation work. The project team in the iPMO should recommend corrective and preventive actions to the change control boards at the central office. More importantly, ongoing adjustments of equipment or a system installation to fit the local reality often results in a need for change. This stage is the primary source of change requests. Change management is a challenging task for the project team in an iPMO.

5.1.3.4 Change order and control

Change order and control was a very important subprocess for this construction project. About 50% of the observed message groups were associated with this subprocess.[4] Those message groups reflect various issues to which the project team in this context needed to pay appropriate attention. Figure 5.5 presents an activity diagram defining the change order and control subprocess.

In the construction industry, drawings are the most important technical documents that the project team uses to execute the project work and train and instruct the installers and locally hired contractors and subcontractors.

[4] The relevant message groups include numbers 2, 5, 6, 7, 11, 13, 14, 15, 17, 20, 21, 22, 23, 28, 31, 33, 35, 39, 41, 42, 43, 44, 48, 49, 52, 53, 55, 60, 61 and 62.

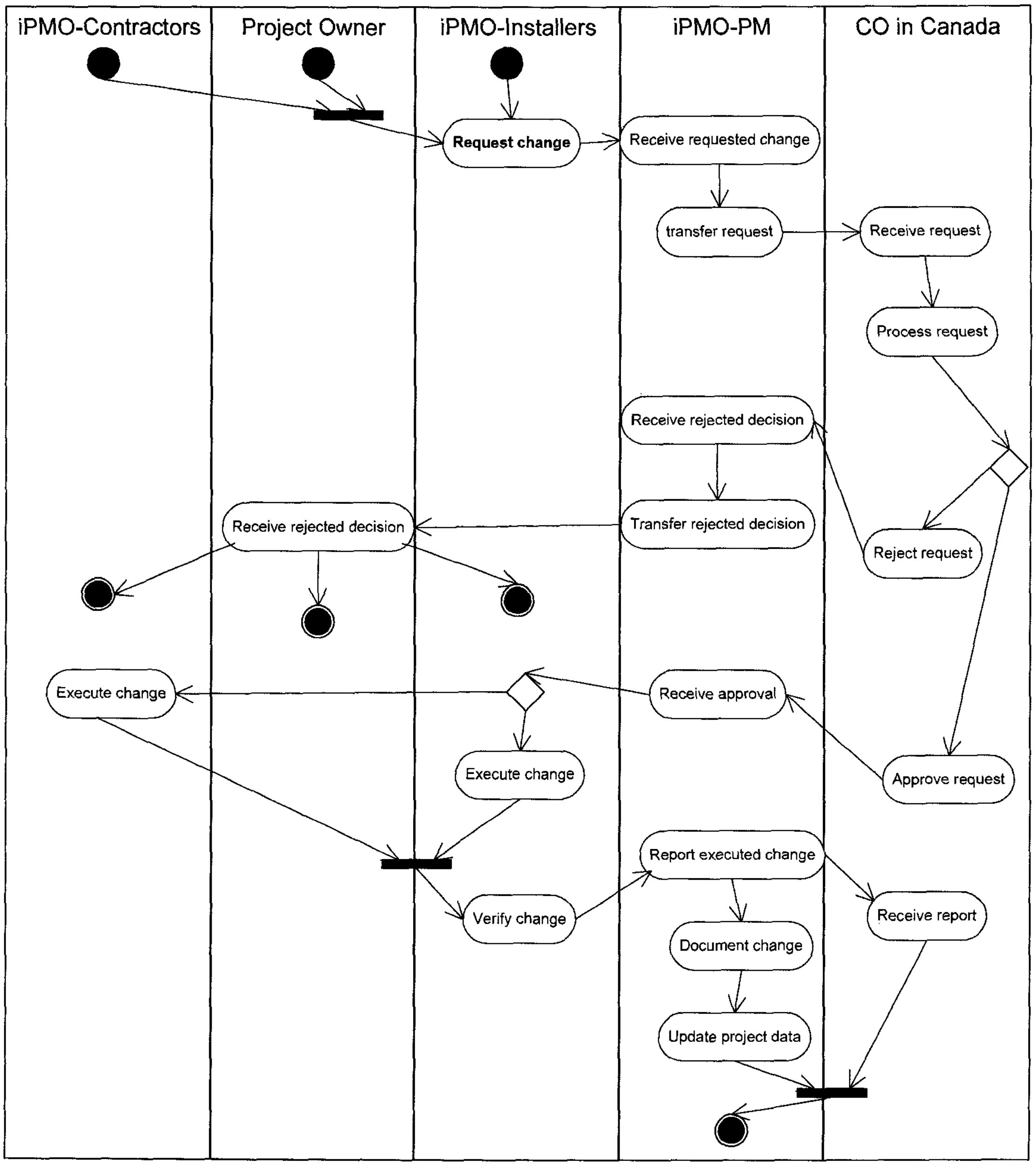

Figure 5.5 Change order and control

During the design phase of a project, the designers and decision-makers have to make assumptions and rely on their experience with previous projects to create a design when many elements associated with the local iPMO environment are still unknown. Accordingly, change requests often arise due to the adjustment of a system installation, replacement by a better option, or application of local safety or technical norms. For instance, in our case, one item of equipment did not function well in the local conditions.[5] Because the decision-makers for change control were at the CO, the iPMO project team needed to transfer the change request information to the CO and request the change. In this distributed work context, efficient responses by the decision-makers at the CO were often a big concern.

The main difficulty for the change control boards at the CO in Canada was that they were unable to evaluate a change request because they did not have enough information.[6] To help the change control board at the central office make decisions more efficiently, the iPMO team, especially the project manager, needs to make a very clear statement about the requested change. The change request should include detailed information on the reason for requesting the change, the potential impact of the change, if applied, to any other project work, the correlation with local environmental factors and regulations, and the various possible options recommended.

In this distributed change control review and evaluation subprocess, the main difficulty for the iPMO was that they had to stop executing the project work, and wait for a decision to be made by the CO.[7] If an iPMO can help its change control board to make decisions in a timely manner, the issues of project work pending due to change control procedures will be effectively resolved.

Keeping the well-trained installers hired directly by the iPMO available is also an advantage for a project team in handling the issues associated with resource availability requirements due to changes. The project team in the iPMO has to discuss and negotiate with the contractors or subcontractors again concerning resource requirements when the approved or imposed changes force the project team to adjust the resources used. These discussions or negotiations should be concluded on the basis of clear documentation of

[5] See message group number 48 in Appendix A.
[6] See message groups 5, 6, 13, 14, 52 and 55 in Appendix A.
[7] See number 43 in Appendix A.

the associated costs added to or deducted from the original contract value, so that the final payment issue, if any, can be settled easily at a later stage.

Even though some of the requested changes may not involve any change in costs, it is also important to document the technical aspects of the change. For example, when the iPMO project team in our case reviewed the drawings and checked the on-site situation, they found that another location for the access door would be better and requested a change from the CO. At the same time, they checked with the hired contractors and concluded that no additional costs would be incurred due to this change. When the change request was approved and the contractors were authorized to make the change, the process was very easy.

However, the timing of a change request and approval is critical to the result of the requested change. If, for example, the change evaluation is delayed and the contractors have to install the door according to the previous agreement, any change in the location of the door will involve rework and additional costs. The project team in the iPMO found that it could be very hard to handle the consequences of the processing and approval of change requests in this distributed work environment.

This again highlighted how important it is for an iPMO to help its central office to make decisions efficiently. Lack of change process documentation was a common issue for both the iPMO and its central office in Canada. Various people mentioned in their messages that they were facing difficulties or confusion because they did not know when and how the requested changes would be evaluated and processed.[8] To solve this issue, we propose in our subprocess model that the iPMO project manager should properly document well evaluation and decision process for requested changes.

Many change requests also originated with the project customer. Often change requests from customers are associated with the unique local project environment, which is unknown to the project designers. When such a request is made by the project customer during the construction process, the iPMO project team will find it very challenging to

[8] See numbers 11, 20, 21, 22 and 33 in Appendix A.

study the issue and provide sufficient information to the central office for evaluation. In these cases, the iPMO needs to collect more supporting contextual information regarding the requested change to help the change control boards at the central office to understand the request more easily and make a decision more efficiently.

5.1.3.5 Document and report project work

This is an important subprocess in which a lot of useful project data is produced for documentation. Our observation revealed that in our case a lack of project data reporting and documentation was a common issue to the iPMO and the central office in Canada. Various issues that were identified are associated with this lack of documentation and reporting.[9] Figure 5.6 is the activity diagram for the Document and Report Project Work subprocess.

Documentation of the project execution process is an important task for a project team in an the iPMO. Most importantly, the iPMO project team needs to keep the project participants at the central office informed of the project's status. In addition to the updated project schedule, our project team used weekly reports to transfer project information. The first part of each report was a direct description of the project work performed during the current week and a plan for the project work to be done during the next week. The second part illustrated the administrative work packages that supported the execution of the project installation work. To give the central office a better understanding of the project work execution, many photos were transmitted to the central office together with the weekly reports.

However, our discussions with the project participants revealed that the reporting process was not appropriate to support the evaluation of the project work, especially for people at the CO. One weakness in the team's current practice was that it did not use more structural reporting and documentation procedures.

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[9] See numbers 4, 5, 7, 11, 12, 13 and 14 in Appendix A.

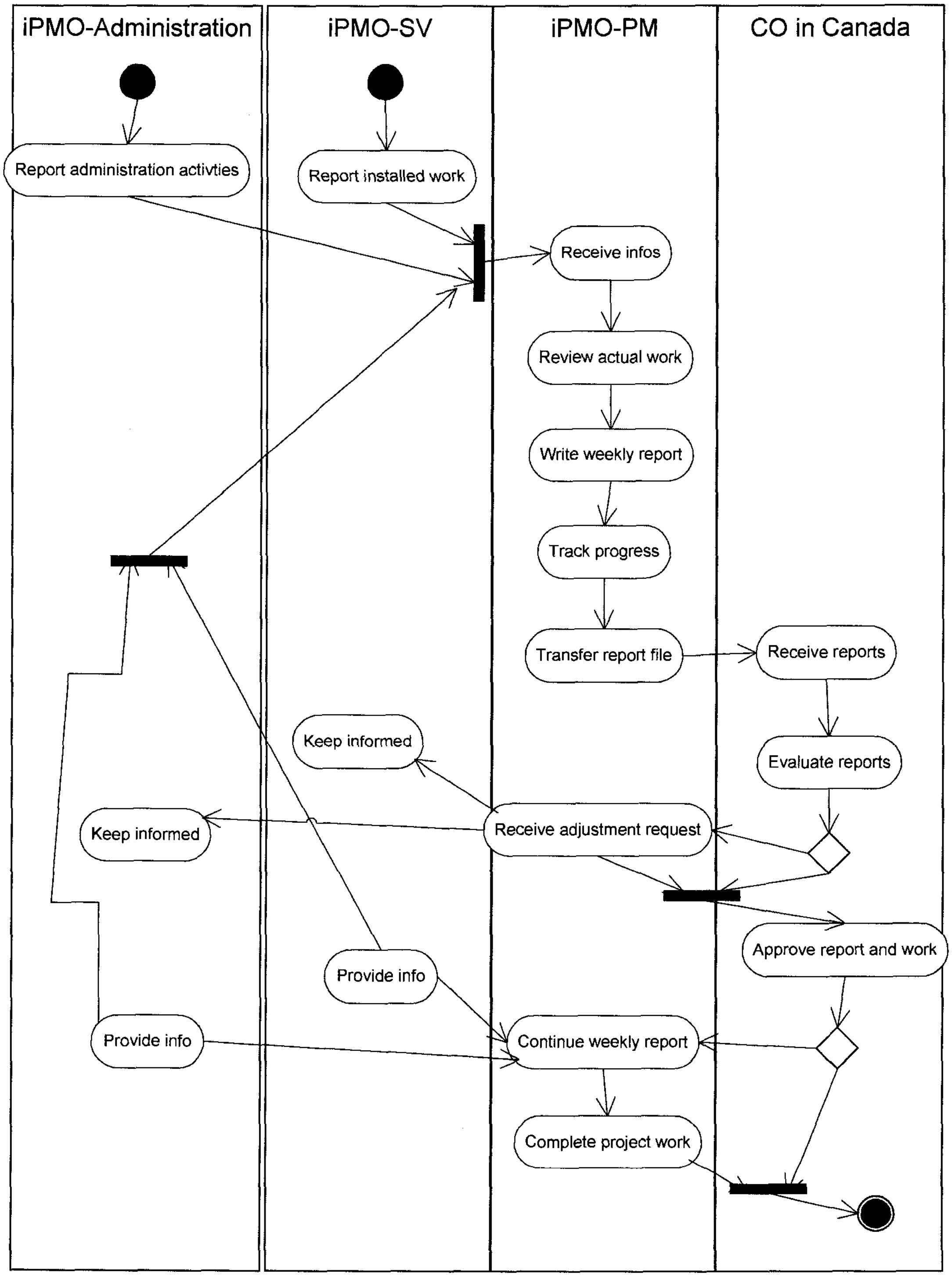

Figure 5.6 Document and report project work

To improve this system, we propose that structural reporting and documentation should include daily reports, weekly reports and updated schedules, monthly reports and updated schedules, daily photos, weekly photos, submittals, transmittals, change orders, meeting minutes, memos, drawing transfers, and requests for information. To facilitate this improvement, the identification and selection of an appropriate information system will also be essential.

The large amount of project data transmitted indicates the importance of on-site project information for the project participants at the CO. However, due to the limited project information system applications, the project's overall communicative efficiency was very low. The project team should have identified and selected an appropriate information system. For example, if a web-based database had been established at the central office, the project team would not have needed to transfer so much project data via email. This information transfer option would have saved the time that the information recipients at the CO had to spend on receiving, downloading, and classifying the emailed information and placing it on the servers, or redistributing it to other project participants at the CO when needed.

In another example, the project team in the iPMO used an individual project planning and follow-up program and transferred the various reports produced by the program, MS Project, from the iPMO to the central office. A web-based program, such as MS Project Server, would have been a significant improvement, facilitating the transfer of project status information transfer. Specifically, the improvements would include:

- Technical supervisors in the iPMO could easily fill in time sheets and document the project's progress, and transfer the data to the iPMO project manager;
- The iPMO project manager would simply need to update and save the schedule and the project participants at the central office could easily see the latest updates on the project's progress, identify emerging problems and find solutions.

Maintaining a project baseline was a more difficult task for the iPMO due to the nature of this international construction project. In project management practice, a project baseline is usually considered to be a formal contract between the project manager and the project sponsor or customer and normally is set only once. However, the dynamic international environment forced the project team in the iPMO to adjust the baseline when necessary after any requested changes were approved. For example, a change request from the project customer could lead to scope changes that entailed the adjustment of project deliverables and substantial additions or deletions of project tasks. The project team sometimes faced issues of substantial additions or losses of resources and substantial changes in resource use costs. In such case, the project baseline had to be adjusted. At the same time, the project team needed to observe the impact of the change on other factors in the project baseline. For example, if the change involved availability, changes of deadline or budget increases, the project team would have to submit the change request to the CO for approval.

5.1.3.6 Do operational testing

When all the project installation work is done, a physical project has been produced. It is now an important task for the project team in the iPMO to conduct a complete evaluation and operational test of the whole project. Testing the project's overall performance in an operational environment is the most effective way to validate whether the customer requirements specified at the outset have been met appropriately. The various kinds of data produced at this stage will be an important information source for the final testing and evaluation report, which could become part of the final overall report for the project's inspection and approval. Figure 5.7 is the proposed activity model for this subprocess.

As some of the equipment used was imported and some was from local markets, ensuring that all the project elements functioned and operated appropriately on an integrated basis was the iPMO project team's main goal. The evaluation and testing should focus on the performance, effectiveness and compatibility of the various subsystems and support facilities that came from different sources.

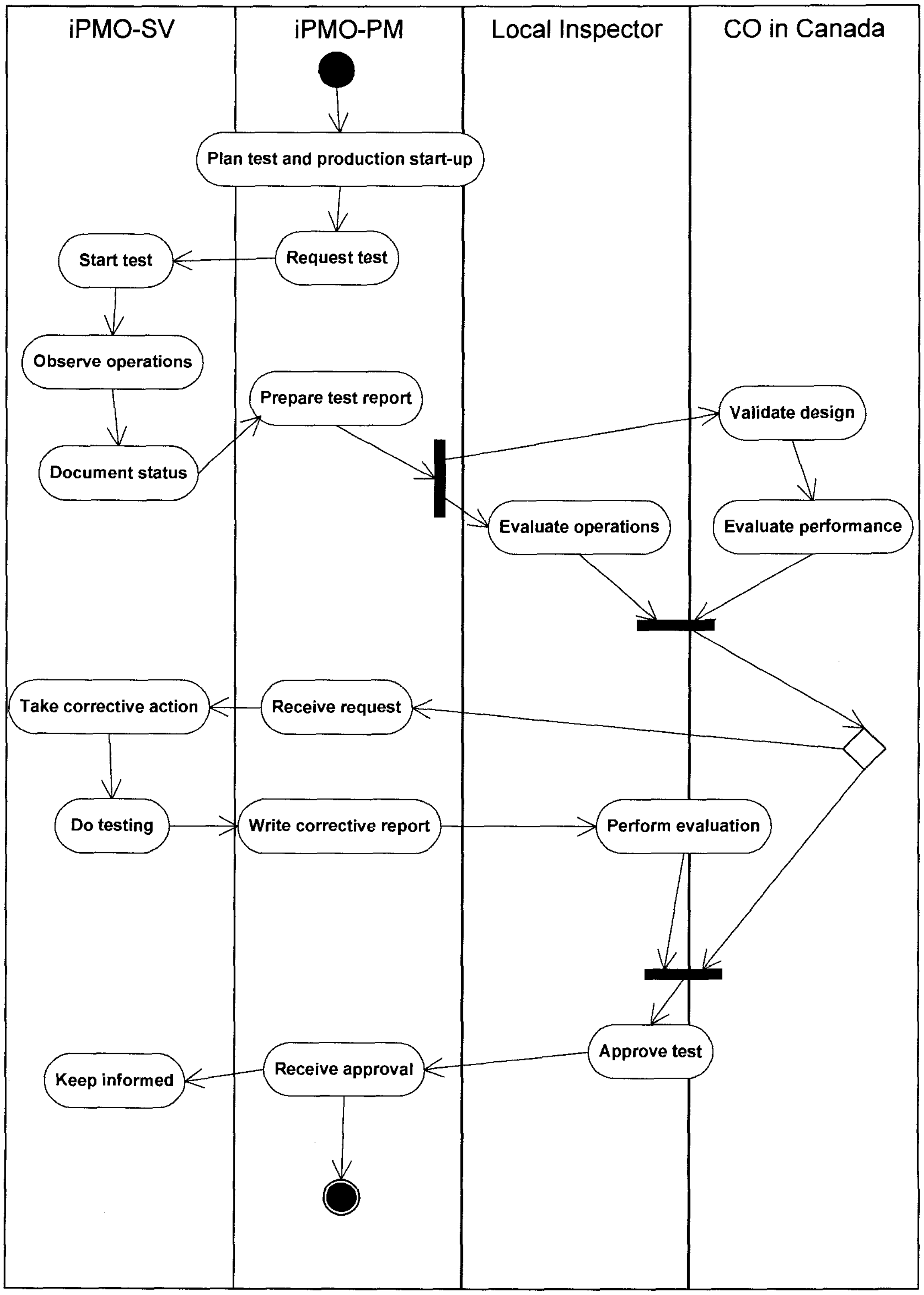

Figure 5.7 Do operational testing

To ensure that the test procedure and results conform to both local regulations and the requirements of the project design, the iPMO needed to organize and provide detailed documents for the local inspector and the internal reviewers in Canada. One issue identified was that the iPMO did not always have the documentation to be given the local inspector[10] at the time of the inspection. To avoid this issue, the iPMO should have documented the necessary data during the project work execution, especially operational test procedures and performance, and made it ready in advance for the various local inspection procedures.

Testing and evaluation usually indicate a need to change an item of equipment, a production software program, a production technology procedure, or a support facility provided by a local source. As such a change could affect many components of the project, change requests resulting from operational tests need to be processed very carefully. For example, a change in equipment is likely to affect software configuration, technical norms application, test procedures and equipment, and possibly some production processes. Any requested change must be evaluated in terms of its direct and potential impact on the other elements of the project.

5.1.3.7 Deliver and close project

About 25% of the observed message groups in integration address various issues that are associated with the Deliver and Close subprocess. However, most of the identified issues are the consequences of work not being well done in the previous subprocesses. For instance, due to the failure to document change orders and control, the project team in this distributed work context faced difficulties getting the information they needed when they prepared the final document. An as-built drawing is one of the most important final documents that the project builder presents to the project owner. Figure 5.8 shows the proposed activity diagram model defining the procedure and addressing the identified issues related to this subprocess.

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[10] See number 30 in Appendix A.

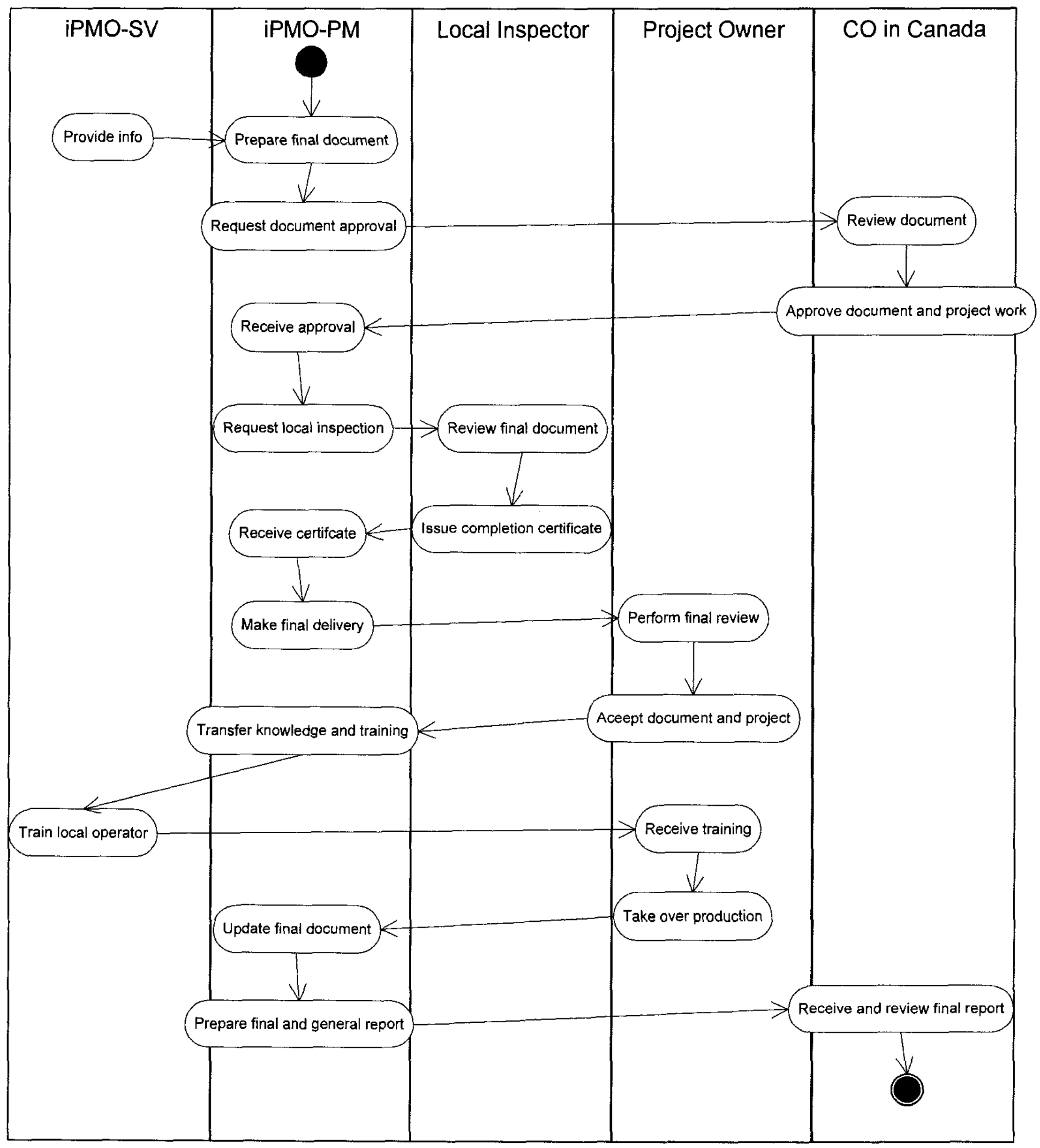

Figure 5.8 Deliver and close project

When the CO in Canada updated the as-built drawing, they did not have the necessary information. They had to ask the iPMO to provide the as-built information. Since this had not been documented and registered, the iPMO had to check the actual construction to get the information.[11] If the project team had followed the proposal in our previous subprocess model and documented the data, this issue could easily have been avoided at this stage.

At the final stage of the project's execution, providing effective training and transferring technology to the local project operators was an essential task for the iPMO project team. One identified issue was that the local project client did not understand the importance of maintaining the right operation status as per the design requirements. To avoid this issue and some other potential issues, the iPMO needed to give systematic training to the local operators. Accordingly, training local operators is an important step in the proposed subprocess model.

5.1.4 Summary

This section proposes a generic model, use case model, and various activity diagram models related to integration management. The generic integration model presents the sequence and relationship among the subprocesses and the main information sources from which the model is developed. The use case model defines, at a high level, the roles of each stakeholder involved and the corresponding responsibilities. The various activity diagrams define the procedures and components, at a more detailed level, for each integration subprocess. Such diagram models provide effective solutions to address the issues identified and the common problems associated with integration management in a distributed work context.

The next section focuses on solving the issues and common problems related to procurement management.

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[11] See numbers 7, 17, 60, 61 and 62 in Appendix A.

5.2 Procurement

This section presents the generic procurement model, use case model, and activity diagram models proposed to resolve the identified issues and common problems associated with procurement management.

5.2.1 Generic procurement model

When the materials or services for an international construction project are sourced locally, effective local procurement processes are essential to the acquisition of the right materials and services with the expected quality and budgeted prices according to the needs of the project construction schedule. As stated in the previous chapter, procurement involves six subprocesses for each local procurement task, considering best practices and other relevant information sources. These subprocesses are Start Up, Prepare PO Document, Request for Proposals, Select Suppliers, PO Administration and Follow-up, and Order Delivery and Reception.

Figure 5.9 is a generic procurement model that presents the subprocesses related to procurement management. As indicated in the figure, like the generic integration model, the generic procurement model is established on the basis of the same three main information sources: interviews and discussions with the project stakeholders, the literature, especially the PMI's (2004) PMBOK®, and the observation of the information flows between the stakeholders in this distributed work context. In the first subprocess, Start up, the project team's effort mainly focuses on the initial evaluation on different resources or services, and decisions concerning which materials and services will be acquired locally by the iPMO. In the second subprocess, Prepare PO document, the main objective of the distributed team is to prepare a well-defined and conclusive PO. Request for proposals is the third subprocess that involves an intensive interaction and communication process. The objective of this subprocess organized by the project team is to facilitate the local suppliers to prepare and provide the right proposal document as the iPMO requires.

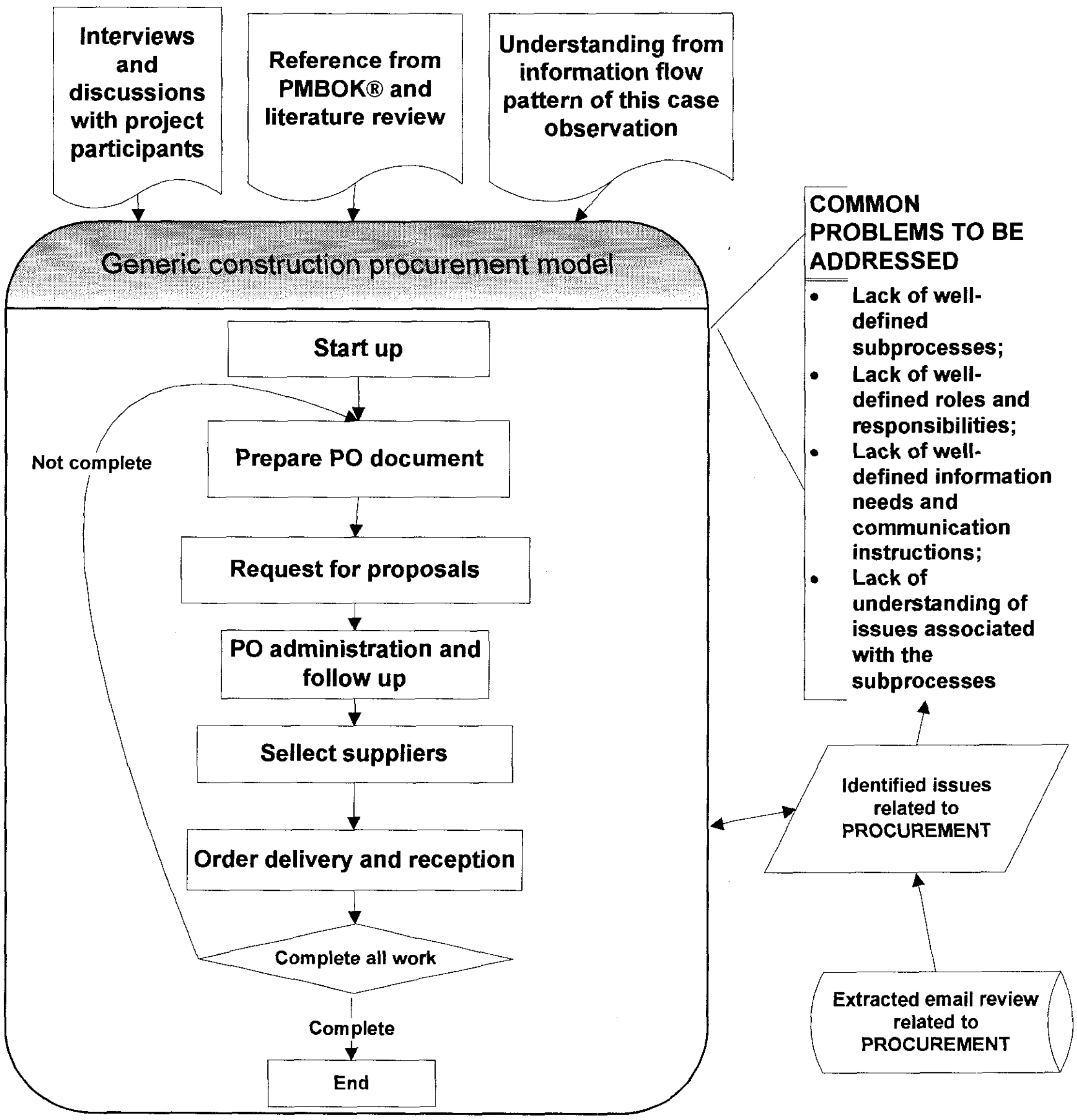

Figure 5.9 Generic procurement model

After the required proposal document is provided by the local suppliers contacted, the main task for the project team is to select suppliers. Select supplier is the forth sebprocess in the proposed generic procurement model. As the project participants at the central office are often the decision-makers, they have to gain the correct understanding of the proposals from local suppliers in order to make the right decision. The interactive and effective communication is a challenge to the project participants in this distributed context. PO administration and follow-up is the fifth subprocess in the proposed generic procurement model. The primary tasks for the project team in this subprocess are to follow up on the production process, perform quality assurance and control, and maintain good change control. Order delivery and reception is the last subprocess in the proposed generic model. The main tasks for the project team are to check and verify if the received items conform to the requirement and performance defined in the contracts with the local suppliers and return the items, if any defect, to the local supplier, or accept those qualified.

This generic model clearly shows the sequences and relationships among the various subprocesses related to procurement management. However, like the generic integration model, it does not provide detailed solutions to address the common problems and identified issues related to procurement management. Similar to our approach to integration, the next section focuses the application of UML techniques and the development of more detailed models in order to resolve such problems.

5.2.2 Use case model

For each local material or service procured, the key stakeholders included the iPMO, the central office in Canada, and various local suppliers or service providers. When we reviewed the message groups for procurement, we found that one typical issue was that various key stakeholders were confused about information requirements and decision-making procedure across the different subprocesses.[12] As presented in figure 5.10, this use case model more clearly defines who will do what work when. The proposed use case model establishes the main framework for the procedures and interactions of the different subprocesses while defining and incorporating the roles of each key stakeholder and the corresponding responsibilities.

[12] Message group 2 in Appendix B is one example of such issues.

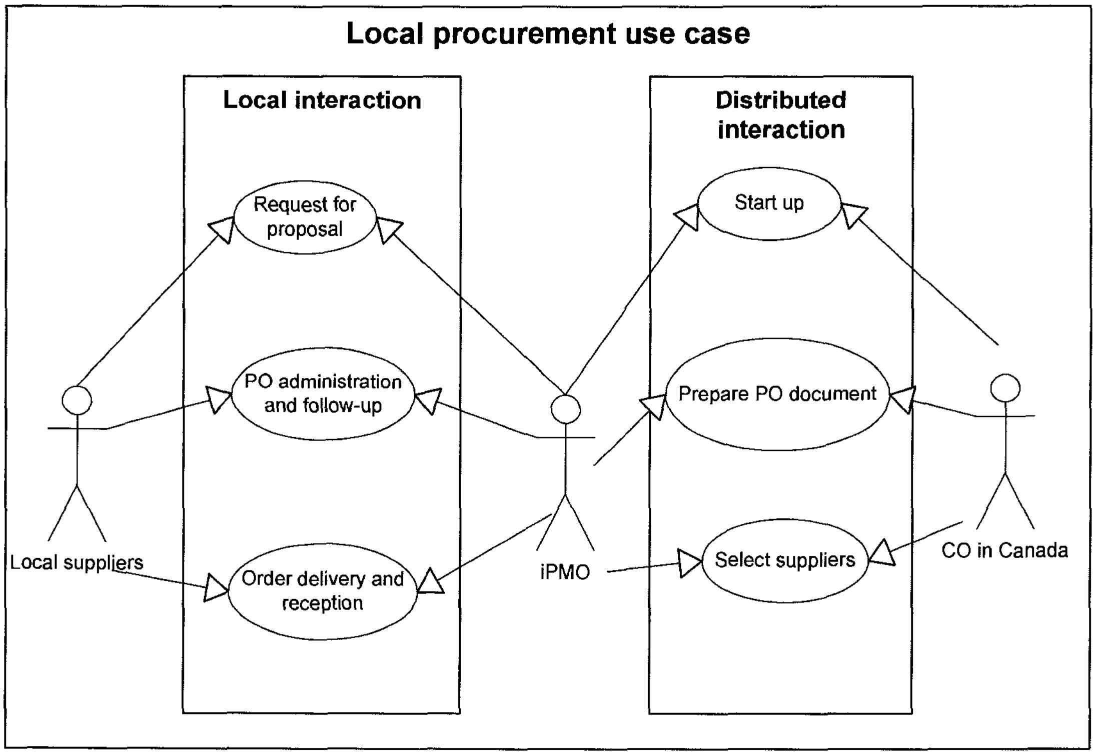

Figure 5.10 Use case diagram for procurement

5.2.3 Activity diagrams for procurement

5.2.3.1 Start up

This is the stage when the different sources of materials or services are initially evaluated and decisions are made regarding which materials and services will be purchased locally by the iPMO. The information on the iPMO's environmental factors provided by the iPMO project manager could help the decision-makers at the central office to gain a better understanding of conditions on the local market where the project was being built. As shown in the use case model, in this subprocess the iPMO and its central office were the two main stakeholders.

5.2.3.2 Prepare PO document

Among the message groups observed in procurement, about 70% covered various issues related to the Prepare PO document subprocess.[13] One typical issue identified was that requirements and specifications were not well defined. Accordingly, in our proposed subprocess model, as indicated in figure 5.11, we recommend that the iPMO project team not pass information on to local suppliers in a rush. Instead, they should study the procurement request from the central office, make sure they understand the contents, and prepare a well-defined and conclusive PO.

The preparation of a PO depends on good cooperation and communications between the iPMO and the central office. The typical PO documents that are used every day at the central office may not apply in the iPMO project environment. The iPMO's key tasks at this stage are to understand the PO requirements and adapt them to the local circumstances of the market where the project is located.

The decision-making for each local PO involves the identification of several qualified potential suppliers and the selection of the one that is able to provide the best product or service. The iPMO needs to make the PO document rigorous enough to ensure consistent and comparable responses from different suppliers.

The adaptation of a PO document to local circumstances requires the project team in the iPMO to carefully study the supplier selection and evaluation criteria usually used by the central office. The technical aspects of appropriately adapted selection and evaluation criteria will be the focus of the iPMO project team. One simple example in our case study was that people at the central office often used the imperial system, which is still commonly used in Canada, to define and describe technical specifications and requirements.

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[13] See Appendix B for details.

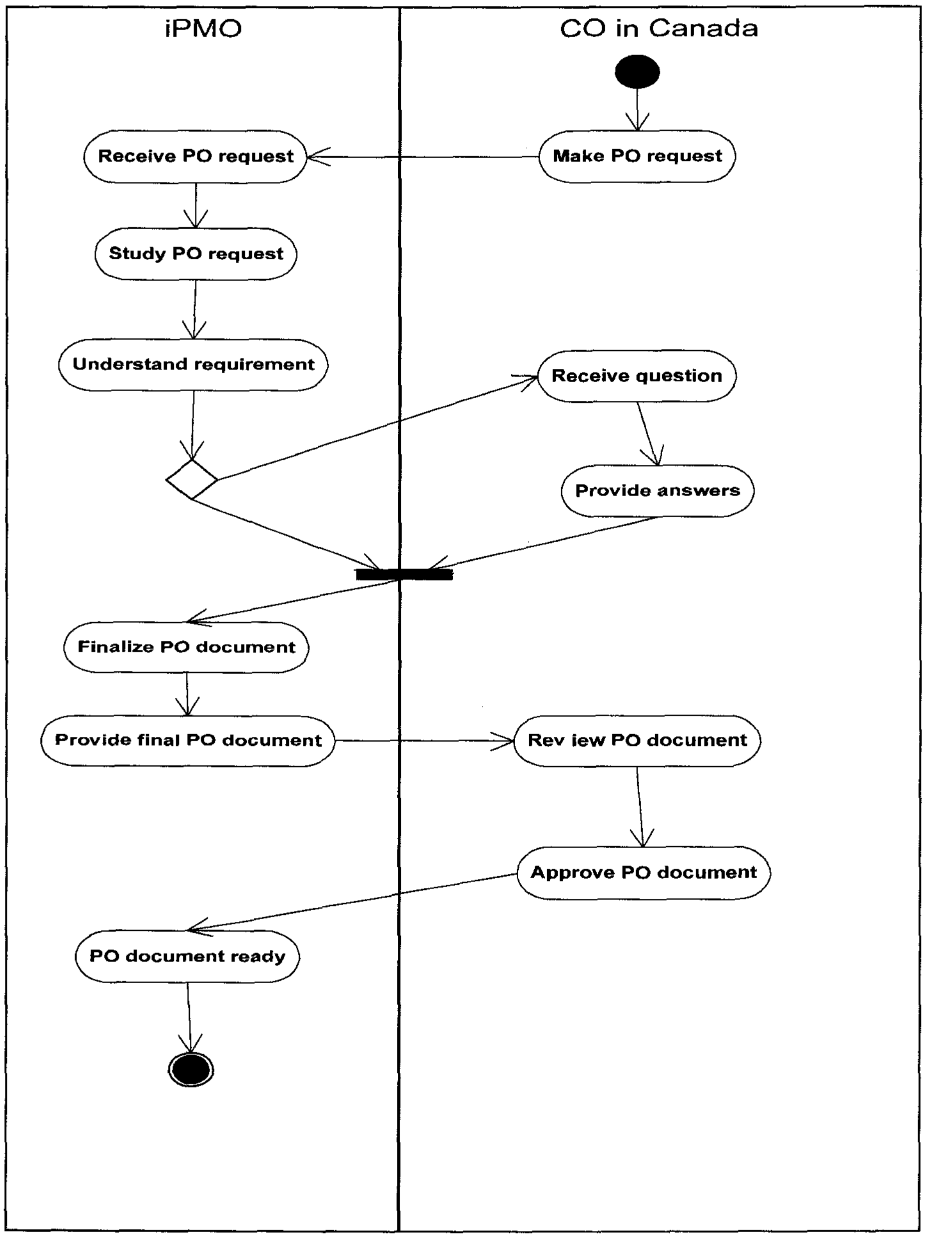

Figure 5.11 Prepare PO document

But PO documents could be very confusing for the iPMO's local suppliers in China if the technical specifications and requirements were measured in imperial units, such as feet, inches, gallons and so on. Given that the metric system is widely used in both everyday life and the construction industry in the local iPMO environment, a critical task for the project team in the iPMO was to convert the imperial measurements into metric measurements for the technical specifications in PO documents. Properly adapted technical aspects also included the identification and application of the technical norms and inspection procedures that are officially used in the local iPMO environment. When the technical norms concerning the design and use of materials applied at the central office were not the same as those applied in the iPMO environment, the difference in technical norms could become an outstanding issue that the project team had to solve. Well-defined technical specifications from the central office might not conform to the local regulations and policies in China due to the different technical norms applied.

To avoid this issue, it is important for the project team in an iPMO to have an in-depth understanding of the application of local technical norms and related inspection procedures. The project team in our iPMO mentioned that their team had faced a lot of problems and difficulties resulting from the different measurement systems and different technical norms. The solution is that the project team needs to be trained to better understand the different systems and norms applied and address the technical aspects properly, so that they can avoid confusion and misunderstanding on the part of local suppliers. At the same time, the iPMO project team also needs to keep the PO document appropriately flexible, so that it can give suppliers a chance to suggest ways to satisfy the project's requirements.

5.2.3.3 Request for proposals

Request for proposals is a subprocess that involves intensive communication between the iPMO project team and the local suppliers that it contacted. This is an interactive communication process. Figure 5.12 shows the formalization of this process by applying a UML activity diagram. The objective of the mutual communication organized by the iPMO is to help the local suppliers gain a correct understanding of the needs and technical aspects of the materials, equipment or services that it intends to purchase and help them to prepare and provide the kind of proposal document as the iPMO requires.

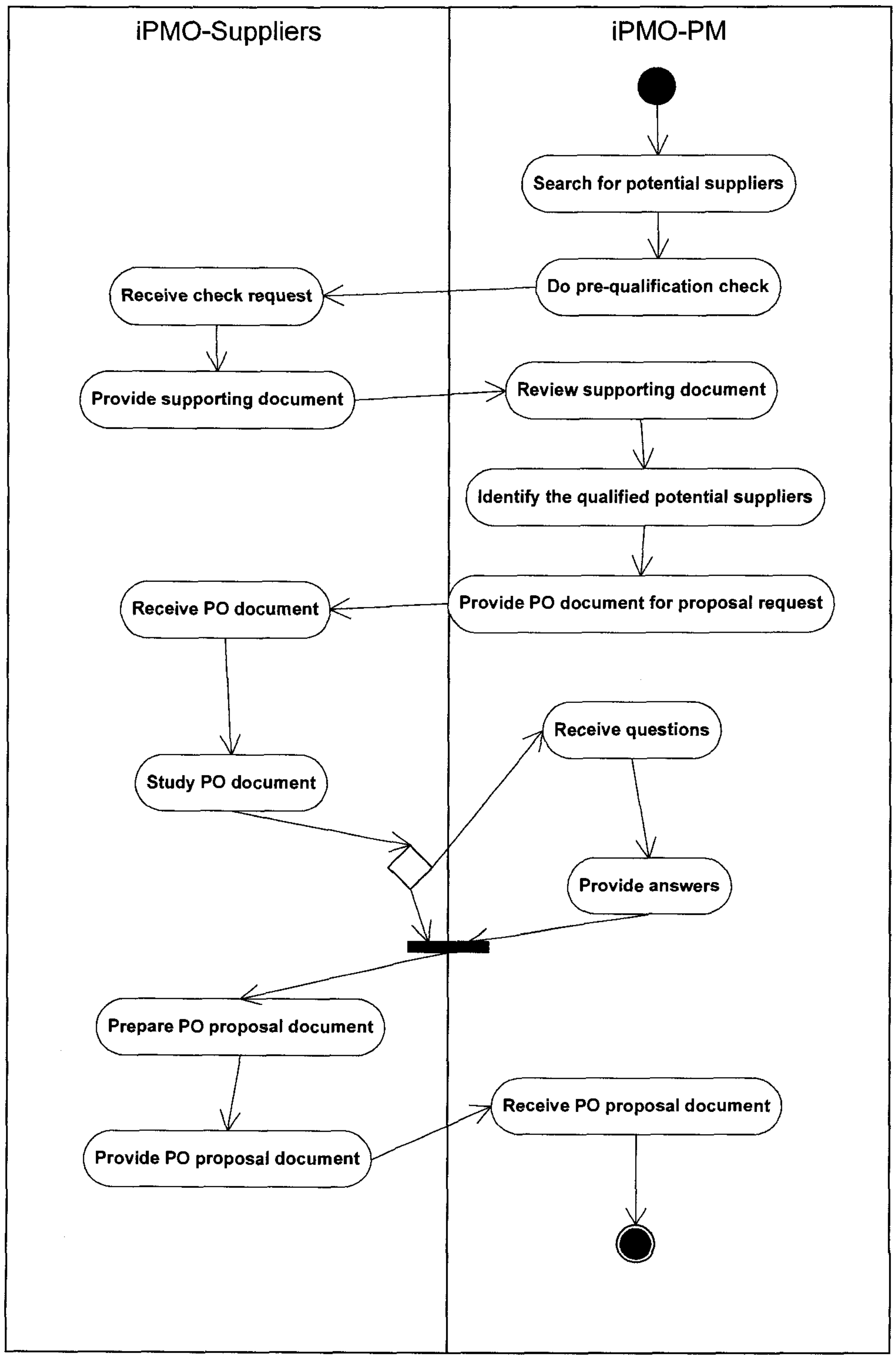

Figure 5.12 Request for proposals

However, in practice in the study case, there was some confusion in the interactive communication process. For instance, as requested by the central office, the iPMO contacted some local suppliers asking for proposals. But many details of the specifications were not clearly defined.[14]

In another instance, the iPMO asked local suppliers to provide proposals, and at the same time the central office and the iPMO were discussing important data for specifications.[15] If an iPMO cannot provide well-defined specifications when requesting proposals, no local suppliers are able to prepare and provide proposals that would meet the needs for the materials, equipment or service that the iPMO expects to acquire. When local suppliers use a poorly defined proposal document provided by the iPMO, major changes in the proposals are unavoidable. Because of this confusion, the iPMO may face more problems later. One real example was that one required component was not installed on locally ordered equipment due to confusion in understanding the order requirements and specifications;[16] this problem was only detected when the equipment was delivered to the project site. If the iPMO had provided well-defined proposal documents to the local suppliers at the beginning of this subprocess, this kind of confusion could have been largely avoided.

As an iPMO project team generally does not have much experience and knowledge of local market conditions and local suppliers, especially at the beginning of a construction project, an extensive information search and consultation with local information sources will be necessary. Identification of the right potential suppliers will be crucial to the iPMO in soliciting high-quality proposals. In the proposal subprocess model, we recommend first that the iPMO should pay a lot of attention to the search for potential suppliers and pre-qualification selection and identification. On-site visits to the various installations will help the project team to identify qualified professional suppliers and

[14] See number 3 in Appendix B.
[15] See number 17 in Appendix B.
[16] See number 2 in Appendix B.

verify their effectiveness and compliance with the technical requirements defined by the PO document.

With the rapid development of business globalization, many companies are now able to provide their services and products almost worldwide. When the products or services that an iPMO is searching for locally are the same as those the central office uses often, then qualified supplier and product identification is much simpler. As the use of the products in earlier projects has documented their technical capability and applicability, the project team usually does not have many concerns with quality when selecting products from this source. The disadvantage, however, is that the price is usually much higher than for products from truly local suppliers. As different product quality levels exist on the local market, the iPMO has to judiciously select a few potential qualified local suppliers for further contact and discussions.

5.2.3.4 Select suppliers

As the project participants at the central office are often the decision-makers when choosing the best supplier to provide a necessary product, interactive communication is required between the iPMO and the central office. In this subprocess, the iPMO and its central office are two main key stakeholders. Figure 5.13 is the activity diagram presenting the Select Suppliers subprocess.

The common issue that a central office often faces, is that decision-makers there cannot make fast decisions on final supplier identification and selection. For instance, in our case, the central office was not able to evaluate local proposals. They said that it sounded very cheap, but they did not know what details were included.[17] Two other similar examples were that the central office had difficulties justifying the quality when selecting local suppliers[18] and had difficulties justifying the quality of local products.[19]

[17] See number 13 in Appendix B.
[18] See number 14 in Appendix B.
[19] See number 24 in Appendix B.

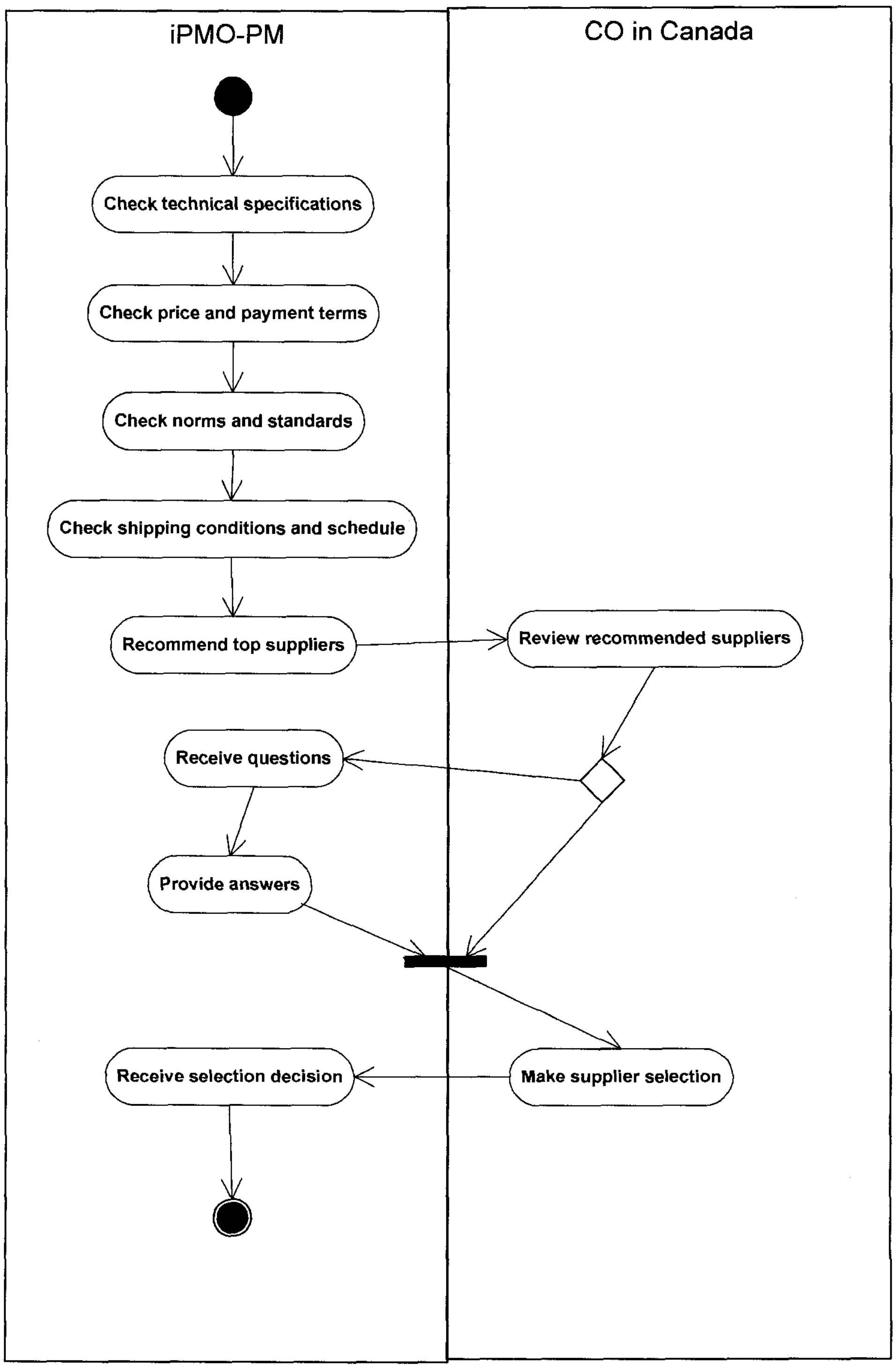

Figure 5.13 Select suppliers

To ensure that the proposals received satisfy the requirements defined by the proposal documents, the iPMO has to first check all details in the documents. As indicated in the proposed subprocess model, this review involves checking for technical specifications, price and payment terms, norms and standards, shipping conditions and delivery schedule.

As the central office does not have sufficient knowledge of the local iPMO environment and market conditions, appropriate recommendations of the top qualified proposals by the iPMO will help it to make the right decision. These recommendations should include not only the technical aspects but also verified background information on the business's size, production capacity, local reputation, and references. Especially when it is the first time that a product is being purchased from a local supplier, the project team should ask the supplier to provide references from earlier customers. The project team in the iPMO can then visit these customers to verify how well their projects were executed. Verified references can become very important supporting evidence for the decision-makers at the central office in conducting their evaluation and selection.

When the technical requirements are met by qualified suppliers, the commercial terms and conditions will become the primary determinant of supplier selection. One misunderstanding by the participants in our case project was that the lowest proposed price represents the lowest cost. In reality, the proposal with the lowest price is more likely to lead to problems if the supplier proves unable to provide the products required according to the project schedule.

The investigation of this case study revealed that the project participants mainly used a subjective approach to identify, recommend and select local suppliers. Due to the limitations of this method, personal prejudices could not be avoided. A more quantitative approach to the overall assessment and comparison of all proposals is required by the project team, especially decision-makers. If a quantitative screening and rating system is established and applied, the iPMO project team could also save a lot of time spent on communications with decision-makers at the central office and discussions or negotiations with local suppliers.

5.2.3.5 PO administration and follow-up

Figure 5.14 is the activity diagram for this subprocess. Not many of the identified issues are related to this subprocess. A few issues, as indicated in Appendix B, are the consequences of poorly done work in the previous subprocesses. When work is not done properly in the previous subprocesses, follow-up and interactive communication with the selected suppliers is all the more crucial. The important tasks for the iPMO at this stage are to follow up on the production process, perform quality assurance and control, and maintain good change control.

If the PO involves a large amount of materials, the iPMO project team should follow up much more closely on the production process and schedule and report to the project manager in a timely manner. The iPMO project manager should ensure appropriate coordination between the local suppliers, the materials inventory controllers, and the project installers. The objective is to ensure sufficient lead time for materials supply and safe levels of inventory. The information on material use rates from the installation is essential for the local supplier to determine its production schedule.

If the locally purchased product is a piece of equipment that involves complex components from different local sources, close follow-up on production is even more important. Many unknown factors from the dynamic local project environment, which is often new to the iPMO project team, can become sources of risks that often have a negative effect on project objectives. The iPMO project manager should remain alert to unanticipated risks that could threaten the project's execution.

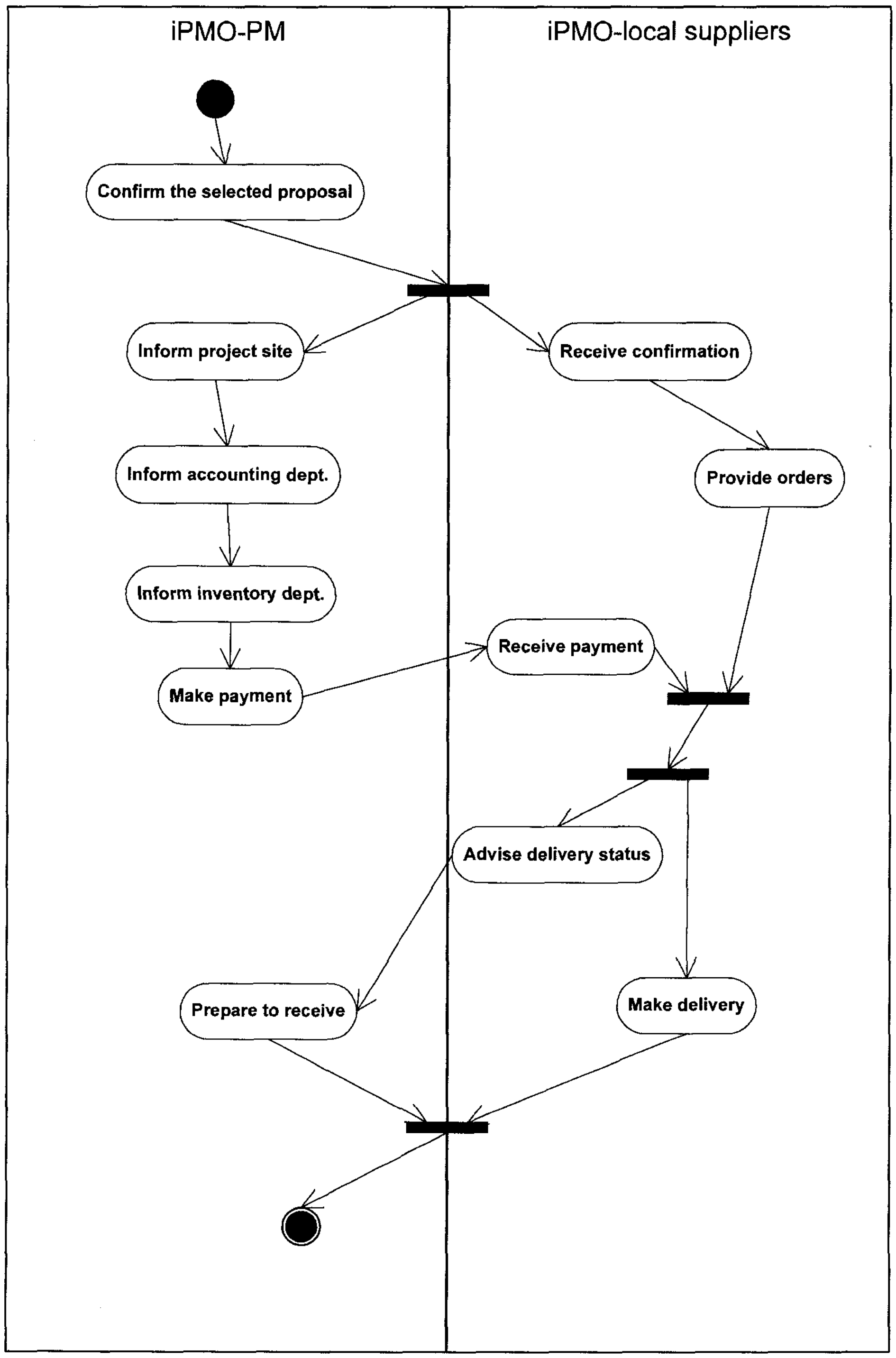

Figure 5.14 PO administration and follow-up

5.2.3.6 Order delivery and reception

Order delivery and reception is the last subprocess within procurement management. Figure 5.15 defines the detailed procedure of this subprocess.

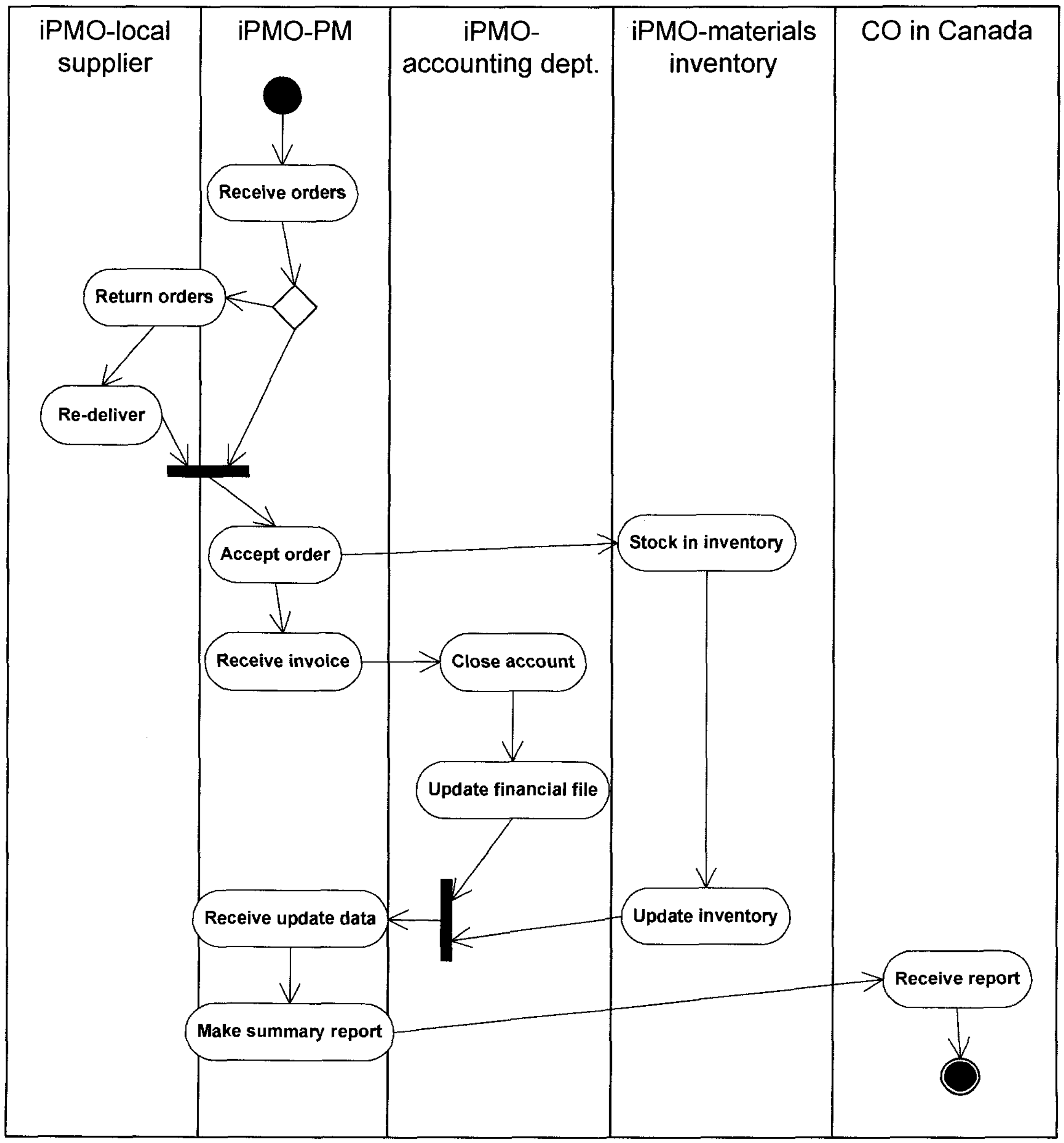

Figure 5.15 Order delivery and reception

The related issue discussed in the email messages was that the iPMO only found that the equipment or materials ordered did not conform to the project's requirements when they were delivered.[20] Discovering problems at this stage is too late, especially in the case of large or very heavy-duty equipment. But if the iPMO had followed the proposals in the previous subprocesses, this problem could have been avoided.

An iPMO should also check any received order to see whether there are any defects in the materials or equipment. This is especially important when the order comes from a local supplier from which the iPMO is receiving a delivery for the first time. If there are any defects, the iPMO must reject the defective or mistakenly sent materials or equipment and ask the supplier to make a new delivery. When the received materials or equipment are accepted, the iPMO will forward them into the materials management procedures, which will be illustrated in the following section.

5.2.4 Summary

The generic model, use case model, and various activity diagram models related to procurement management were developed and proposed in this section. The sequence and relationships among the subprocesses and the main information sources from which the model was developed are presented in the generic procurement model. The use case model for procurement defines, at a high level, the roles and responsibilities of each stakeholder involved. The various activity diagrams for procurement define the procedures and components, in more detail, for each procurement subprocess. The identified issues and common problems associated with procurement management in the distributed work context are resolved by the corresponding activity diagram for each procurement subprocess.

The next section focuses on solution to the issues and problems related to materials management.

[20] See number 2 in Appendix B.

5.3 Materials

This section presents the generic materials model, use case model, and various activity diagram models applied to resolve the identified issues and common problems associated with materials management.

5.3.1 Generic materials model

As illustrated in the previous chapter, materials management includes the following subprocesses: Materials Planning, Acquire Materials, Stock Materials, Issue Materials, Materials Verification and Materials Control. Materials Verification and Materials Control are performed every time the subprocesses of Acquire Materials, Stock Materials and Issue Materials are executed. Figure 5.16 is a generic materials model that shows the subprocesses related to materials management.

As indicated in the figure, like the generic integration and procurement models, the generic materials model was generated on the basis of same three main information sources: interviews and discussions with the project stakeholders, the literature, and observation of the information flows between stakeholders in this distributed work context. In particular, observation of the information flows in this real construction project provides specific evidence of the existence and necessity of each of the above-mentioned materials subprocess. The findings presented in the previous chapter lay the foundations for this generic materials model. Similar to the generic models for integration and procurement, this generic model clearly shows the sequences and relationships among the various subprocesses related to materials management.

Like the generic integration and procurement models, it does not provide detailed solutions to address the common problems and identified issues related to materials management. As in the approach to integration and procurement, the next section focuses on the application of UML techniques and model development in more detail in order to solve such problems.

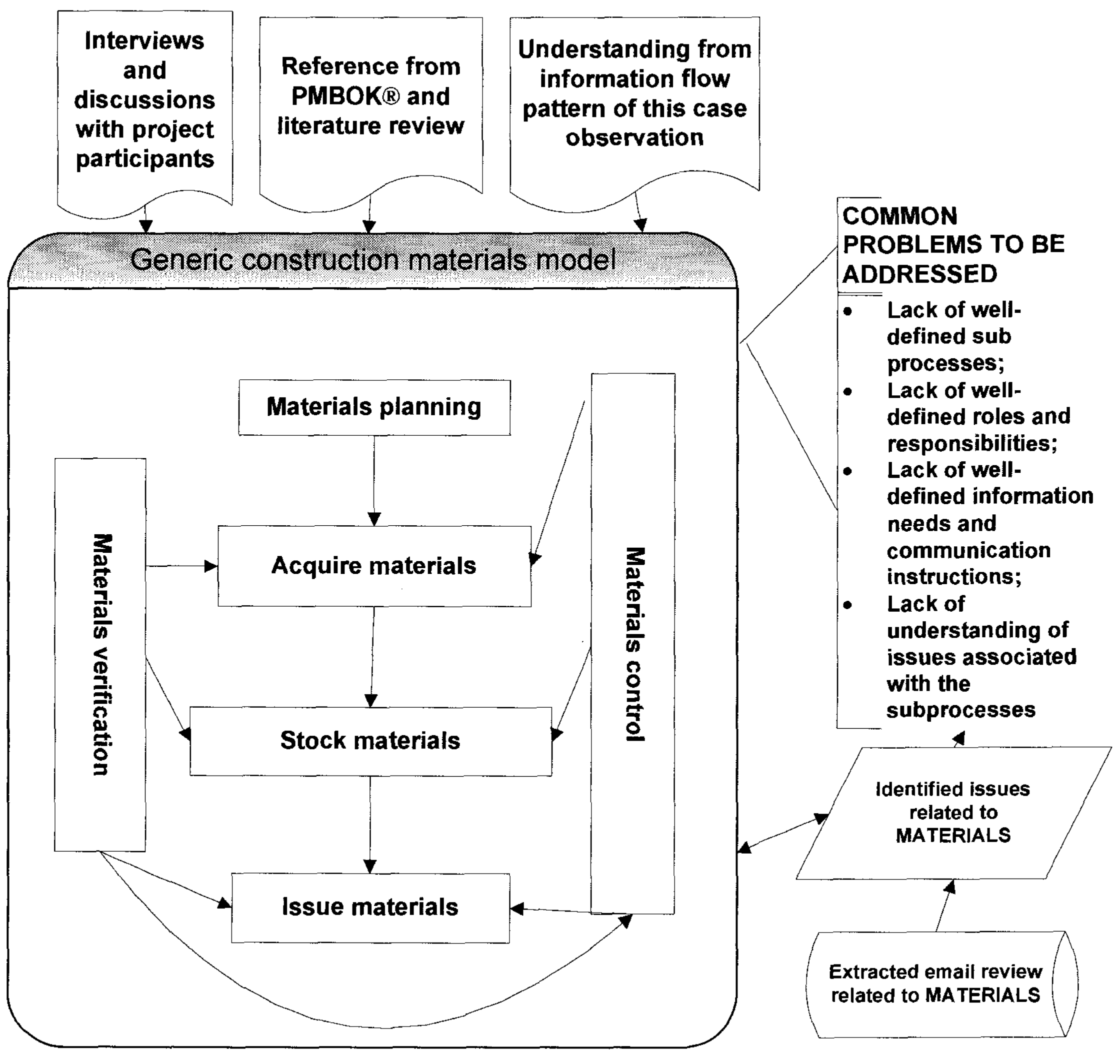

Figure 5.16 Generic materials model

5.3.2 Use case model

Some of the problems we identified are concerned with materials in the construction environment, and others reflect the special issues associated with project implementation in an international environment, such as the information needed to satisfy the local inspection procedure. As mentioned in previous chapters, a common issue is that there is no well-defined materials management model in the case study project. A further issue is the lack of clear definitions of roles and responsibilities for effective materials management. To resolve such issues, the proposed use case model in figure 5.17 includes all of the necessary subprocesses for materials management, and all of the key stakeholders involved. In this case, the key stakeholders, as indicated in the use case model, include the central office in Canada, the iPMO project manager, the iPMO technical supervisors, the iPMO installers, and the iPMO inventory controllers.

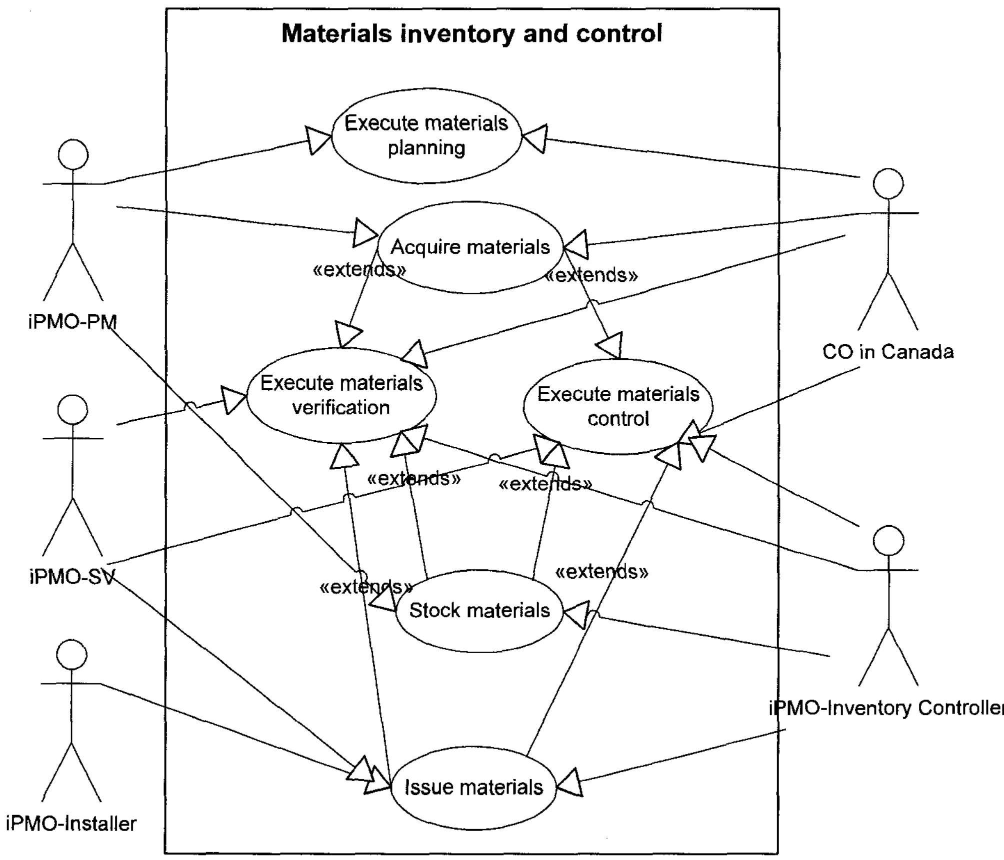

Figure 5.17 Use case diagram for materials

Any project team needs to plan and manage materials to contribute to a successful project. The goal of the planning process in materials management is to identify and define the essential materials required to execute the project. The processes inside the executing process group include all the physical and administrative activities associated with materials. The aim of the materials management process is to coordinate the materials required by the project team to integrate and perform all the defined project activities in accordance with the project management plan, and more specifically, to complete the work related to materials as defined in the project materials management plan.

The objective of materials management in the monitoring and controlling process group is to observe materials usage, identify the potential problems related to materials in a timely manner, and take corrective actions when necessary. With this continuous monitoring mechanism, the project team will have insight into the status and performance of materials flows and use, and instantly find out any problematic processes that require special attention. The monitoring and controlling process group in materials management not only monitors and controls the work related to materials being done within a group, but also coordinates and integrates all related process interactions and data flows among the process groups.

5.3.3 Activity diagram for materials

5.3.3.1 Materials planning

As indicated in figure 5.18, materials planning determines the materials required to complete the project and creates the materials management plan. Materials may come from inside or outside the organization performing the project. The materials management plan may include when and how materials will be acquired, stocked and issued to satisfy the project's requirements .

Before proceeding with materials planning, the project team needs to consider the necessary inputs required for this process. The inputs for materials planning include enterprise environmental factors, organizational process assets, project scope statement, work breakdown structure, Work breakdown structure (WBS) dictionary, and project management plan. When creating the materials management plan, enterprise environmental factors and systems related to materials must be considered. Specifically, these include items such as government- or industry-defined materials standards, conditions on the market, commercial materials databases, and the project materials management information system.

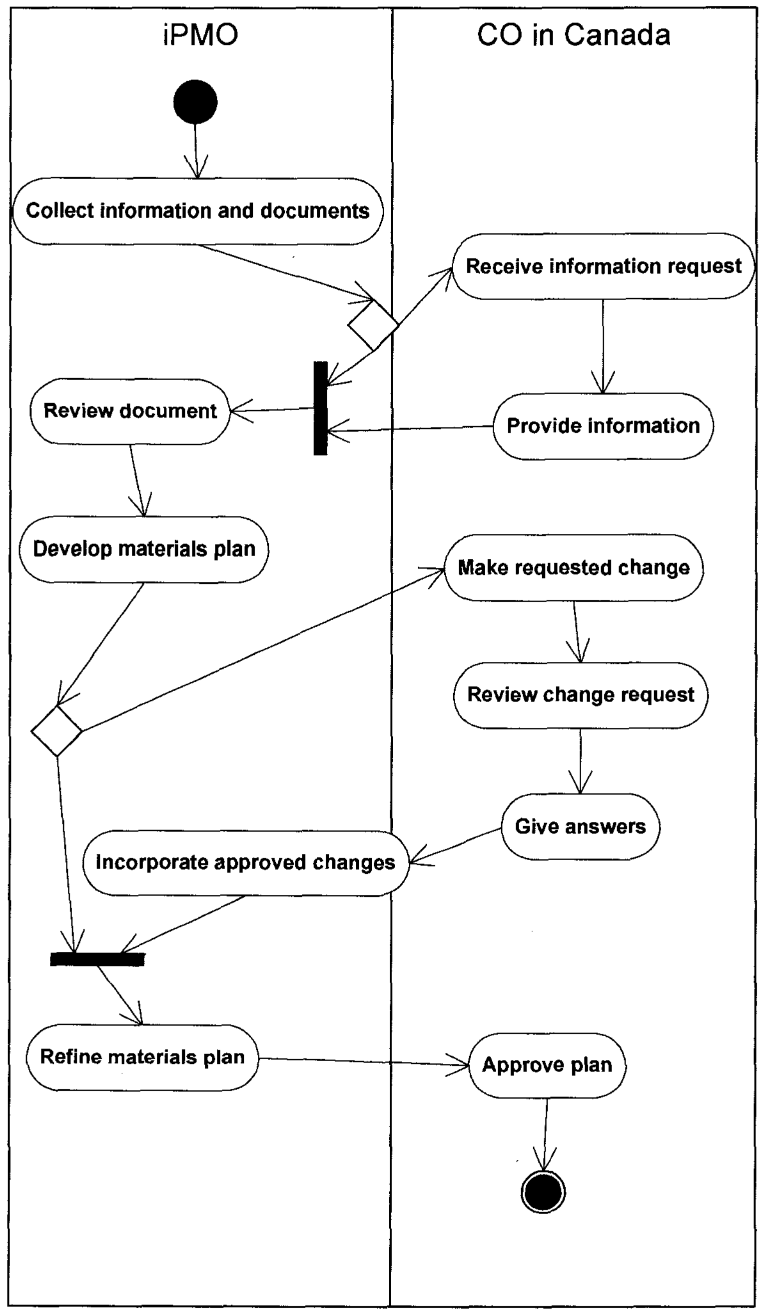

Figure 5.18 Materials planning

Another valuable input for materials planning is organizational process assets. The project team should access and evaluate the data from this source, which usually reflects the knowledge of materials management practices acquired in previous projects performed by the organization. A few examples related to materials are the organizational materials policy and standards, defective materials management procedure, materials change control procedure, etc.

When developing the materials management plan, a project team needs to consider the project requirements and strategies, as defined in the project scope statement. The project team can use the list of deliverables and acceptance criteria for the project in the project scope statement to establish the high-level list of materials and the corresponding selection criteria. The work breakdown structure and WBS dictionary provide the project team with detailed information on resource requirements, including materials. With this information, the project team is able to refine the high-level materials list established on the basis of the information in the project scope statement and develop a more detailed materials management plan and materials list.

The project management plan can also be an input for planning materials. Subsidiary plans such as the quality management plan and the procurement management plan provide guidance for materials planning. Since planning is interactive in nature, the outputs from other planning groups are also often considered when planning materials. Among those outputs, the items produced by the activity resource estimating process and the schedule development process are most relevant to materials planning. Activity resource requirements, activity attributes and resource breakdown structure give the project team more precise information about the type and quantity of materials required for each activity. The resource calendar specifies the quantity of each material available during each availability period, whereas the project schedule and schedule baseline define the specific time when each material will be required for a scheduled activity. A well-established project schedule will guide the project team in checking the availability of materials and assigning each available material to a work activity in the materials planning process.

The goal of materials planning is to produce the output required by the project team to organize and coordinate the materials needed to perform the project. The output can include the materials management plan, materials list, materials attribute, and requested changes.

The materials management plan describes how materials will be managed, from identifying the materials requirements through project closure. The materials management plan can include the following items, for example:

- Coordinating the materials sourced by procurement and the materials needed to execute the project activities. This could effectively solve two identified issues: there were not enough imported materials to complete the planned work,[21] and it was not clear to the iPMO whether the planned work would be done using imported materials. [22]
- Developing policies on using lead time to acquire materials from procurement or any other materials source. A well-defined project management plan and materials management plan will avoid the confusion related to one issue, namely that the iPMO and the central office had different understandings of the timing of the work.[23]
- Establishing the directions to be given to the project team members in charge of materials management on acquiring, stocking and issuing materials.
- Developing the form and format to be used for following up and controlling materials flows.
- Identifying the appropriate information system to manage materials or including a module for handling materials in the project management information system.

The materials list is a comprehensive list of all materials that the project team plans to use in the project. It includes materials identification, corresponding to the activity identifier defined in the activity definition subprocess of the project integration

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[21] See number 7 in Appendix C.
[22] See number 20 in Appendix C.
[23] See number 20 in Appendix C.

knowledge area. A well-defined materials list will resolve the identified issue that a piece of imported equipment did not fit local needs[24] and one material needed locally was not on the materials plan.[25] Materials attributes describe the features and status of each material on the materials list. The attributes for each material include the materials identifier, materials code, materials description, materials requirement dates, imposed dates, constraints and assumptions. These attributes give the project team important information so they can follow up and monitor materials flows and status in the various materials management processes.

The materials planning process can generate requests for changes that may affect the materials availability, cost budgeting, installation methods and procedures, and human resources requirements as well. Requested changes for materials are evaluated and processed by the integrated change control process.

5.3.3.2 Acquire materials

Figure 5.19 presents the acquire materials subprocess in detail. Acquire materials is the process of obtaining the materials needed to complete the project. The inputs for this subprocess can be enterprise environmental factors, organizational process assets, and outputs from the materials planning process, such as the project materials management plan, materials list, and materials attributes. Selected sellers and resource availability from the select seller subprocess can also be important inputs to the acquire materials subprocess.

Project materials are acquired from all available sources. The make-or-buy decisions in the purchasing and acquisition planning process of the project procurement knowledge area will determine whether the materials will come from internal or external sources. The characteristics of enterprise environmental factors that need to be considered include such important factors as the availability, performance and cost of materials. The project team members in charge of materials management need to know when each material will be available, whether this materials has been used in a previous project

[24] See number 22 in Appendix C.
[25] See number 31 in Appendix C.

what the results were, and how much each material will cost. The lack of such information is one issue identified in the case study and observation. One example was that an item of imported equipment did not work well for this project.[26]

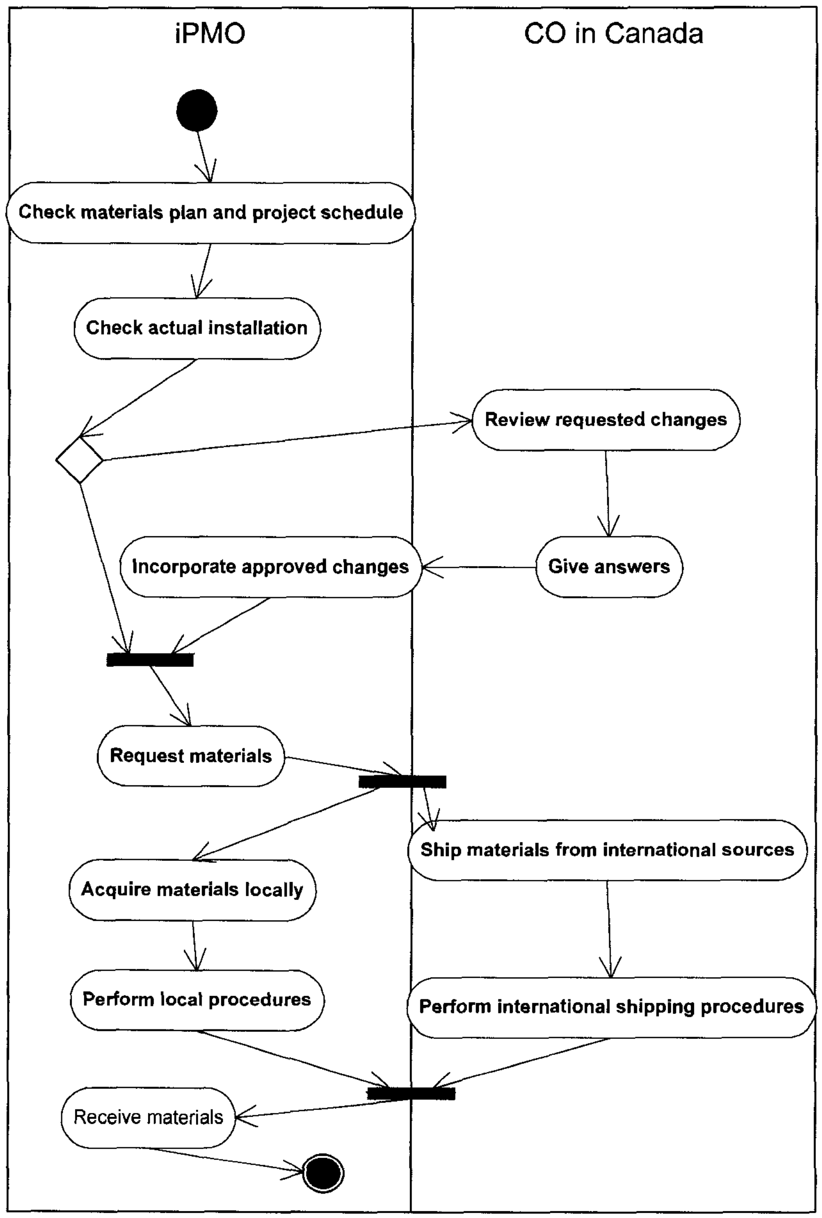

Figure 5.19 Acquire materials

[26] See number 30 in Appendix C.

Organizational process assets in the project-performing organization usually include plans, policies, procedures and guidelines governing materials identification, selection and use. Those assets are an important information source for the project team concerning materials acquisition. The procurement department in the project organization can help the project team to acquire the materials it needs if they must be sourced externally.

The materials management plan, along with the project schedule, specifies the time when each material will be needed. It also defines the specific policies and procedures the project team must follow in terms of how, where and when to acquire the needed materials. The materials list from the materials planning process provides the project team members in charge of materials management with a detailed guideline. Our case observation revealed that a lack of this kind of information was one common issue that the iPMO often had to face. Various real examples concerned this issue. For instance, an instruction document did not contain the necessary information for the installed models.[27] Another example was that a motor for an imported machine was missing, and there was no indication on the imported equipment list.[28] If the iPMO had had the necessary information, such as the materials management plan and materials list, their difficulties in this regard could have been avoided.

The outputs of the acquire materials process are the materials received, the updated materials management plan, the updated materials list, and requested changes. As specific materials meet the specific needs of project work activities, changes in the materials management plan may be needed. The project team may find that the planned materials do not fit the project's specific needs. This also triggers changes in the project management plan. Requested changes are reviewed and evaluated through the integrated change control process. Other reasons for changing the materials management plan and the project management plan include changes in market conditions, materials availability, materials cost and budget, and quality standards applied. The updated

[27] See number 11 in Appendix C.
[28] See number 14 in Appendix C.

materials list and materials attributes mainly reflect the new status of materials due to the fact that some of the materials have been physically received.

5.3.3.3 Stock materials

Figure 5.20 presents the activity diagram for this subprocess. The inputs to the stock materials subprocess may include received materials, the materials management plan, resource requirements, the materials list and the project schedule. The materials management plan identifies inventory strategies and the plan to ensure that materials are available to perform project tasks. Received materials are an output of the preceding subprocess, and constitute physical items that the project team must arrange properly in the stock materials subprocess. The materials list updated during the acquire materials subprocess provides the data on the actual materials received and can serve as a database for the project team when they handle the materials received.

One objective of the stock materials process is to establish the links between materials and tasks and improve the visibility of available materials. The lack of a link between the materials in stock and the materials required to execute the project proved to be a serious problem in this case study.[29] Various real examples from Appendix C are evidence of this issue. For instance, the message group dated February 24, 2005, indicates that the central office asked whether the site inventory had a certain list of materials, and the iPMO had to physically check the inventory to find the answers. Another message group dated April 1, 2005, addressed a similar topic, mentioning that the central office did not have clear information about the materials stocked on the project site. The iPMO had to check the inventory and find the materials to determine the answer.

To achieve the objective of establishing links and improving visibility, resource requirements in terms of materials are needed as an input. These resource requirements are an output of the activity resource estimating process, in which the types and quantities of materials required for each scheduled activity are described. The project

[29] See numbers 2, 7, 8, 9, 12, 14, 17, 24, 25, 27, 29 and 33 in Appendix C.

team should also check the project schedule and schedule baseline developed in the schedule development process, to find out when each material will be needed.

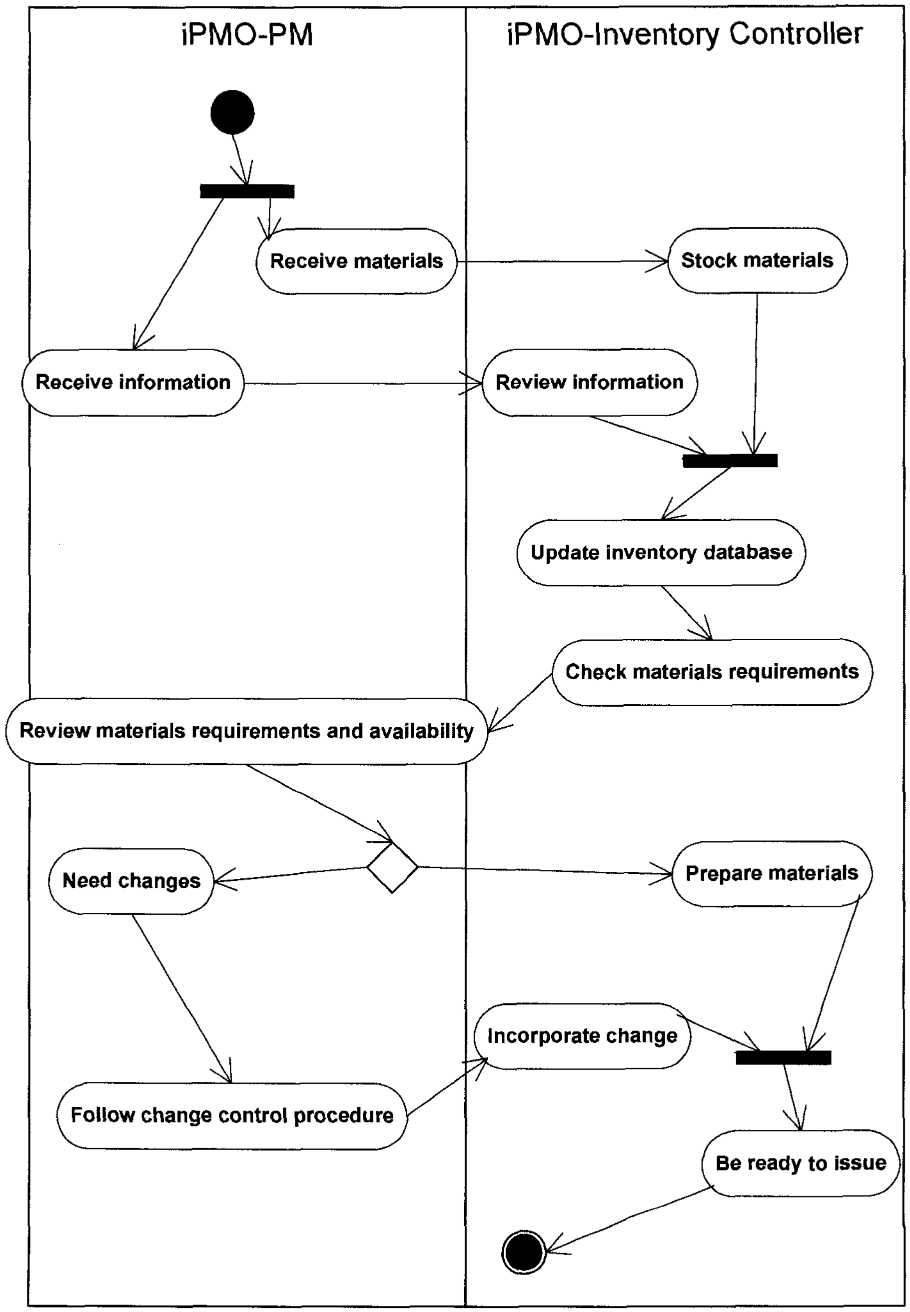

Figure 5.20 Stock materials

In the resource estimating process, the types of materials that will be required, their availability and the quantity needed are estimated. In the stock materials process, the project team needs to verify those estimates from the perspective of materials, and confirm to the iPMO project manager whether the required materials are available in inventory or request a change in the type, quantity or availability of materials. Accordingly, materials availability and requested changes will be the output of the stock materials process. An updated materials list may also be an output of this process, reflecting the change in the status of materials from reception to inventory. In our proposed subprocess model, as shown in figure 5.20, the iPMO inventory controller is responsible for maintaining and updating the inventory database, checking materials requirements, and preparing for materials accordingly. At the same time, it is the iPMO project manager who is responsible for reviewing materials requirements and availability. This interactive cooperation will reinforce the link between materials available in inventory and materials required for project work.

In current industry practice, inventorying materials on a construction site involves the consideration of many factors including access and traffic routes, materials storage and handling, administration buildings and welfare facilities, and equipment workshop and service (Thomas, Riley, & Messner 2005). There are three materials storage areas on a construction site: the semipermanent outside storage area, staging area and workface. Certain principles of construction site materials management have been proposed as guidelines with broad and immediate applicability to construction practices.

Even though the just-in-time system is the least applicable to materials management (Ibn-Homaid, 2002), it is still often recommended by researchers in the construction industry. Accurately timing the delivery of the equipment and unloading it on its foundation will avoid warehousing and multiple handling efforts and costs (Kini, 1999). The delivery rate of materials should be compatible with the installation rate of the field crew (Thomas et al., 2005). When that works, just-in-time delivery is preferable. However, more coordination between the materials suppliers and the work crews who use the materials will be required. Our case study revealed that making materials available in the inventory in advance with the proper lead time reduces the risk of not having them at hand when needed. The balanced solution for inventory is to have the materials available when needed and at the same time to maintain the minimum possible warehousing. The upcoming tasks on the project schedule, with their materials requirements, provide a forecast to the project team member in charge of materials supply. Optimizing and updating the project schedule is required to ensure that the project team gets the right information and prepares the materials needed according to the schedule. In the case of a construction project, the project team has to reconfirm the manufacturing and transport schedule according to the construction plan and feed back to the manufacturer as a reference for planning and revising the production plan (Cheng & Chen, 2002).

5.3.3.4 Issue materials

Figure 5.21 illustrates the detailed procedure for the issue materials subprocess. The two outputs from the stock materials subprocess—materials availability and materials list update—are the necessary inputs for the issue materials subprocess. The main objective of this subprocess is to meet the requirements for materials in time to perform the project tasks. The schedule baseline is an important input to issue materials. The outputs of this subprocess may be issued materials, an updated materials list, and requested changes. The materials list update may reflect the changes in the status of materials from inventory to their issuance and release.

The issue materials subprocess represents an interface between materials and the physical execution of project work activities. Effective coordination and interaction are essential to supply the materials in a timely manner so the project work can be performed. The materials management process is executed according to the materials management plan, whereas project work is performed in line with the project schedule. The project schedule and materials planning are developed sequentially and the two processes are not tightly integrated (Ibn-Homaid, 2002). This need for integration highlights the importance of cooperation and coordination between project members for the materials management process and project work execution, especially in this subprocess, when the project team members have different functions.

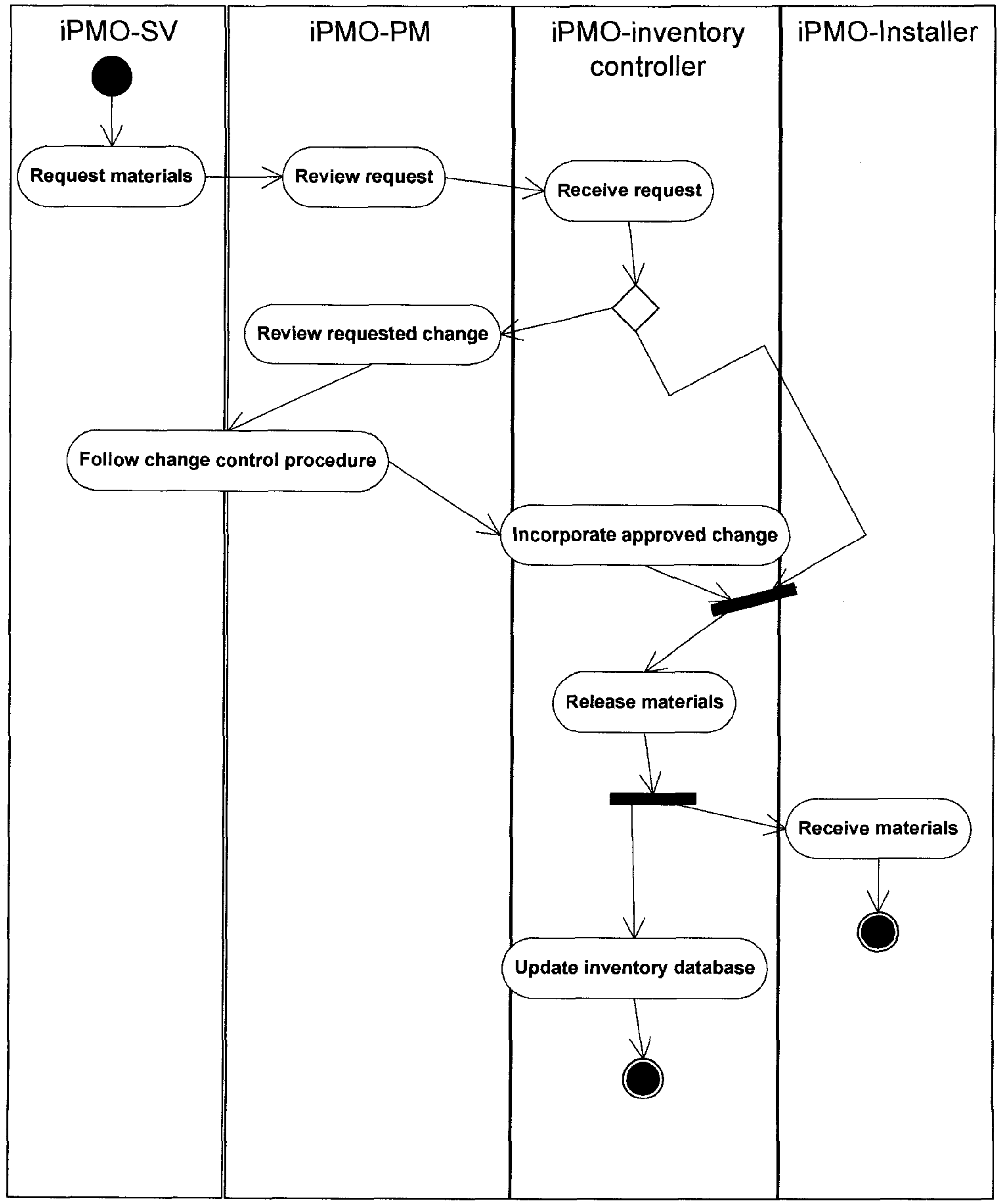

Figure 5.21 Issue materials

For complex systems, the project team member in charge of materials supply should visit the construction site to become familiar with the details of the installation's status. Keeping in close touch with the team members in charge of the project installation work and obtaining frequent status reports are vital to ensuring that the required materials are supplied on time.

In the proposed issue materials subprocess, the key stakeholders include the iPMO project manager, the iPMO technical supervisors, the iPMO installers, and the iPMO inventory controllers. The iPMO technical supervisors will be the people who request the materials from the project manager. After a review, the project manager will pass the request on to the inventory controllers. If this request does not involve a request to change materials, the inventory controller will release the requested materials to the installers. When the request does concern a change of materials, the materials change request will be reviewed and processed according to the change control procedure. The main issue identified in this subprocess was that missing or incorrect materials were only detected when materials were released and installed.[30] As this issue is the consequence of inadequate work in the previous subprocesses, it could be largely avoided in this subprocess if the iPMO followed the recommendations proposed for the various materials management subprocesses.

5.3.3.5 Materials verification

Materials verification is the process of obtaining formal acceptance of the materials acquired, stocked and issued. As illustrated in figure 5.22, the three key stakeholders in this subprocess are the iPMO inventory controller, the iPMO project manager, and the central office. The verification process includes reviewing each material to ensure that it meets the specifications and quality standards. If this procedure is well done, the iPMO will not face the typical issues identified in this case study.[31] The documentation of materials verification will improve the accuracy and visibility of materials flows and

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[30] See numbers 7, 12, 14 and 17 in Appendix C.
[31] See numbers 1, 3, 6, 7, 10, 12, 14, 17, 18, 25, 26, 33, 34, 35, 38 and 39 in Appendix C.

status in all three subprocesses, namely acquire materials, stock materials and issue materials. The inputs to the materials verification subprocess may be the materials management plan, materials received, stocked or issued, and materials attributes.

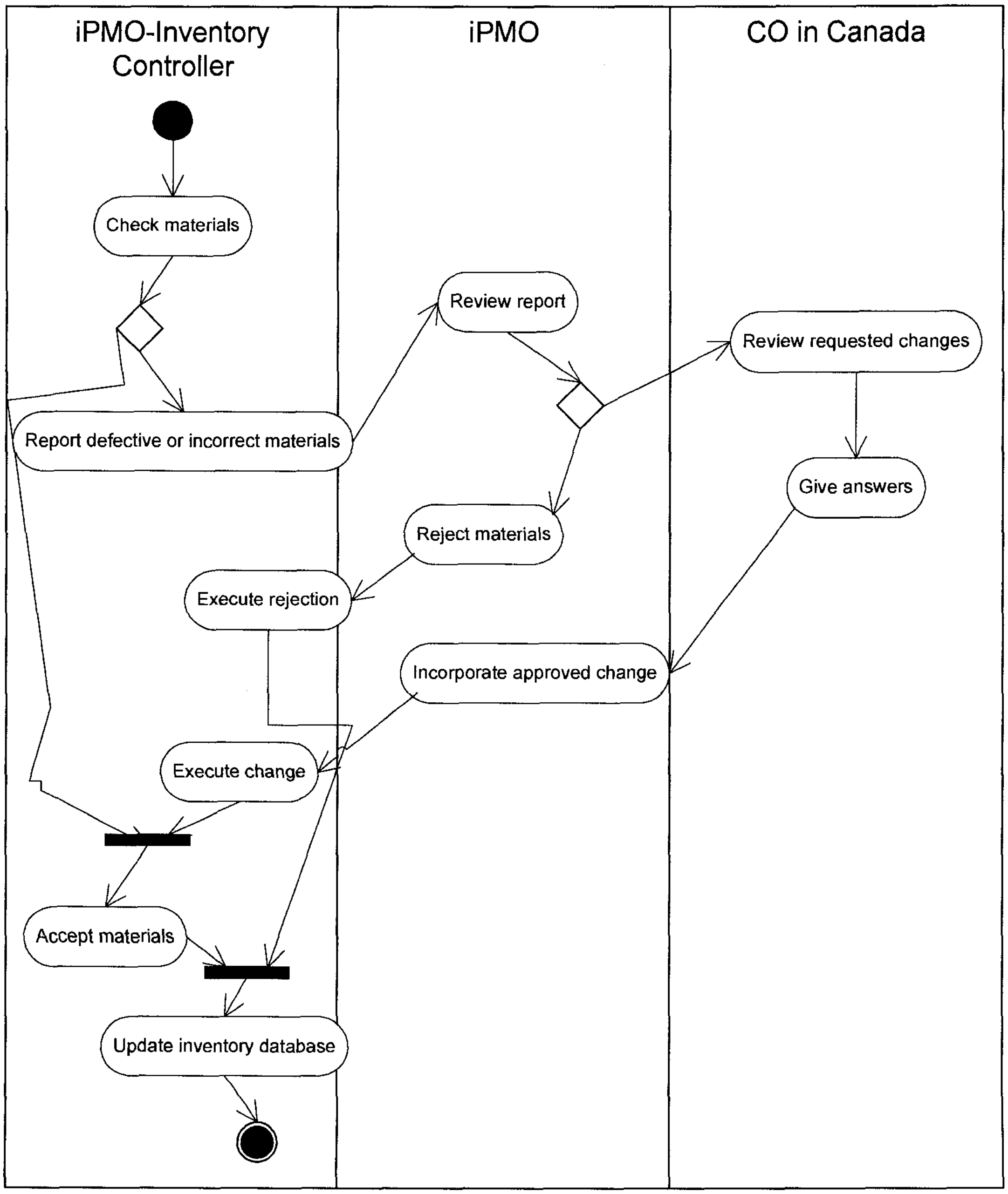

Figure 5.22 Materials verification

The project materials management plan contains the high-level materials description and acceptance criteria, whereas the materials attributes contain the technical specifications for each material, which form the components of the detailed definition of each one. The materials verification process produces three outputs: accepted materials, requested changes and recommended corrective actions. In this process, all materials are checked and the accepted materials are documented. The materials that are not accepted are also documented, along with the reason for non-acceptance. The non-accepted materials trigger change requests and recommendations, which are also the necessary output of this management process. Requested changes generated by this process are evaluated and processed in the integrated change control process.

5.3.3.6 Materials control

The materials control subprocess identifies and evaluates the factors leading to changes in project materials and controls the impact of those changes. Materials control establishes and defines a management process, as indicated in figure 5.23, by assuring that all requested changes and recommended corrective actions associated with materials are processed though the integrated change control process. The inputs for the materials control subprocess include the project materials management plan, approved change requests, work performance information, the materials list, and materials attributes.

Work performance information reflects the status of the scheduled activities being performed to accomplish the project work. The status of deliverables and reported percentage of physically completed work constitute information on the status of materials applied to the corresponding project work. More importantly, the status of change requests, corrective actions, preventive actions, and defect repairs from the work performance information may have a direct, immediate impact on the use and organization of materials. The approved materials change requests represent modifications of the project materials baseline, which is derived from the approved project materials management plan, materials list and materials attributes.

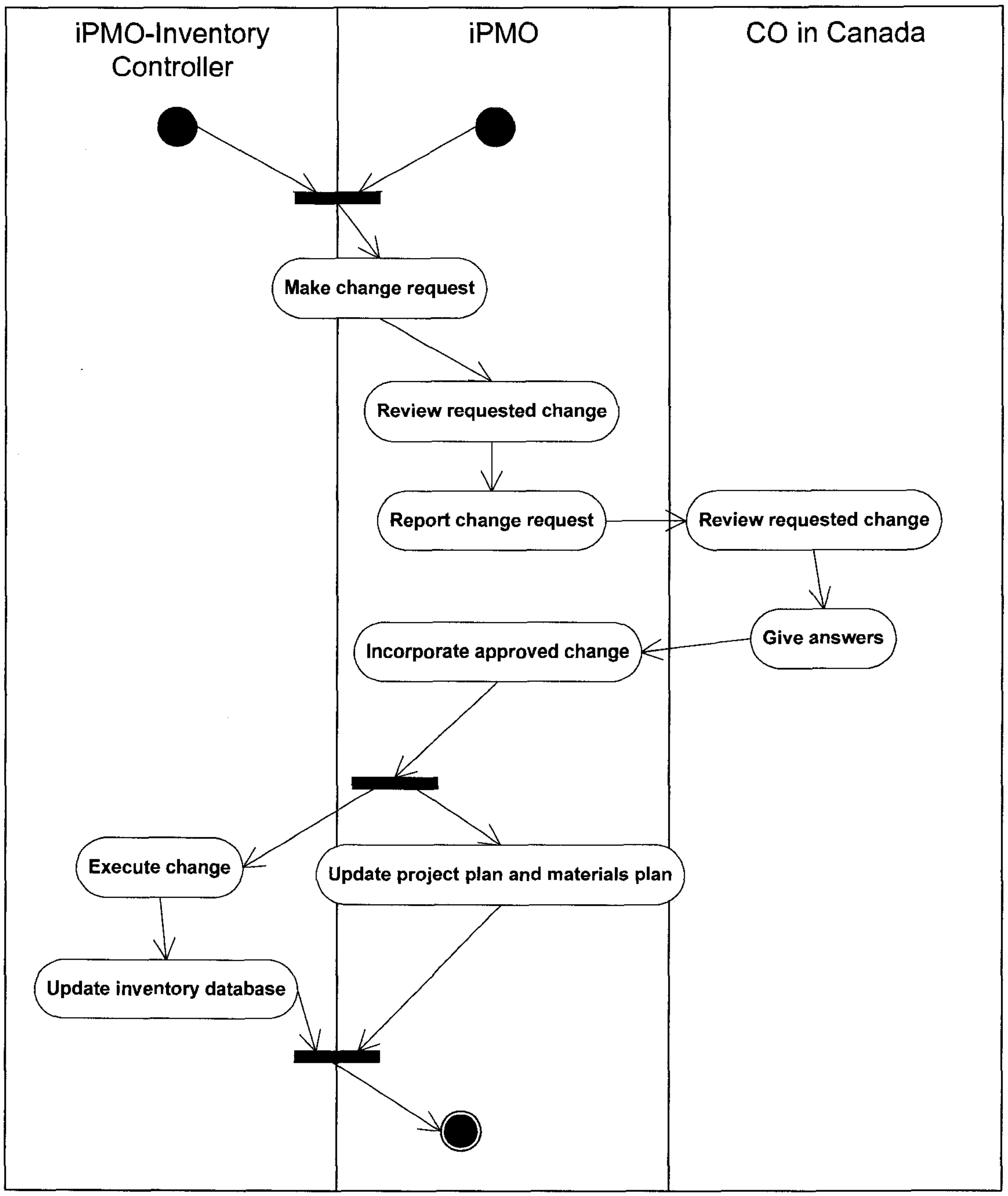

Figure 5.23 Materials control

The project team usually needs a materials change control system that is integrated into the overall project management information system. The change control system of the organization executing the project will define the procedure of and level for change requests and approvals. In this case study project, the central office in Canada serves as the integrated change control board, which also included the change control for materials. In this distributed work context, one issue identified was that there was a lack of documentation and records concerning changes in materials.[32]

To resolve this problem, our proposed subprocess model recommends that an iPMO should keep all the relevant data in their materials change records and incorporate these changes when updating the inventory database, project plan and materials plan. Another main issue identified in the case study was that preplanned equipment or materials did not fit the needs of the current project work.[33] As this is usually the consequence of work that the project team did not do properly in the previous subprocesses, this main issue could be resolved if the project team would follow the recommendations in our various proposed models.

However, there are still some situations in which changes in materials will be required. The materials control process produces various outputs including the materials baseline update, materials list update, materials attribute update, requested changes, recommended corrective actions, organizational process assets updates, and project management plan updates. Materials control can generate requests for changes. For example, in our case, a local construction procedure triggered the use of a local material.[34] Such requested changes are processed through the integrated change control process. In this situation, the proposed subprocess model could serve as a framework for the project team to follow.

A request for a change in materials could also include a recommendation for corrective action. A recommended corrective action is any measure recommended to bring the

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[32] See number 28 in Appendix C.
[33] See numbers 15, 22, 19 and 30 in Appendix C.
[34] See number 32 in Appendix C.

expected performance of materials into line with the project management plan and materials management plan. Organizational process assets will be updated by including the lessons learned from materials control. The causes of variance in materials flows and status, along with the reasoning behind the chosen corrective action, will also be recorded in the historical database of organizational process assets. When the approved changes in materials have an effect on the human resources use and timing of the project task, the cost baseline and schedule baseline of the project management plan are reviewed and adjusted to incorporate the approved change. The materials baseline will be updated to include the approved change and its impact on any other components contained in the baseline.

5.3.4 Summary

This section focused on the proposal and development of the generic model, use case model, and various activity diagram models related to procurement management. Like the generic integration and procurement models, the generic materials model shows the sequence and relationships among materials subprocesses and the main information sources from which the materials models are developed. The use case model for materials defines, at a high level, the roles of each stakeholder involved and the corresponding responsibilities related to materials management. The various activity diagrams for materials define the procedures and components, in more detail, for each materials subprocess. The activity diagrams, corresponding to each materials subprocess, are effective solutions to address the issues identified and resolve the common problems associated with materials management.

CHAPTER 6
CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCH

The main objective of this research was to analyze various management processes in a real construction project within a distributed team context, and propose effective solutions that are able to address the issues that were identified. The contribution made by this study incorporates the following components:

- The identification and establishment of information flow patterns in a distributed team context. This is described in the first section of Chapter 4.
- The identification of integration, procurement and materials as the three most critical management processes with the largest number of issues that the project team had to handle in this distributed work environment. This is set out in the second section of Chapter 4.
- The investigation of the topics in the most interactive and communicative messages related to integration, procurement and materials, and the identification of various issues affecting processes or subprocesses. This is done in the third section of Chapter 4.
- The proposal of a well-defined subprocess model that is able to resolve the issues identified for integration management and suggest improvements. This is presented in the first section of Chapter 5.
- The proposal of a well-defined subprocess model that is able to resolve the issues identified for procurement management and suggest improvements. This is presented in the second section of Chapter 5.
- The proposal of a well-defined subprocess model that is able to resolve the issues identified for materials management and suggest improvements. This is done in the third section of Chapter 5.

This research was also of practical value to the project-performing organization studied here. The project team will be able to improve the management processes for new projects in a similar execution environment by using the proposed process and subprocess models. Our argument is logically supported by the following illustrations:

- The generic models for integration, procurement and materials are developed on the basis of observation and incorporation of the best practices applied in this case project, the PBMOK® framework, and communication and information patterns. It will definitely be applicable to new projects executed by the same company.
- If the change of the project environment from China to any other country does not change of the nature the issues identified, all of our proposed subprocesses will continue to be applicable to the new project environment. In other words, our proposals in this case study could represent effective solutions for a project team in a new project environment.
- All of the issues identified are process- or subprocess-oriented. None of them are related to culture, language or any other factors that would be significantly impacted by the change from China to another country. Accordingly, our models will remain effective and applicable to new projects executed by the same company.

There are a few limitations on this research process. One is that we only observed information flows between the iPMO and the central office in a distributed work context. As we did not investigate information flows in the local iPMO context, we do not know what the relationships may be among information flows between the project participants in different contexts. In the overall project context, there may be a correlation between information flows in the local team context in the iPMO and in the distributed team context. The correlation, if any, could reflect the extent to which project participants in one work environment depend on project participants in another environment. How the project participants in one context support others in another context in terms of information flows would be a very essential aspect for study and observation.

The second limitation is that this research only focused on the construction phase and did not involve other phases of the whole project life cycle. The identification of problems and difficulties that the project participants may face in other phases and recommendation of an appropriate solution would also be very beneficial to the organization. The third limitation is that this research was conducted on basis of only one case observation and investigation. The most important limitation of one case study is that the findings cannot be directly generalized and applied to other projects.

To overcome these limitations and extend our current research efforts, we recommend that future research activities could focus on the three aspects. Specifically, one aspect is concerned with the identification and recommendation of a suitable project management information system. As we observed, the lack of a suitable project management information system could be one main cause of some of the issues identified in the case study. The investigation and recommendation of an appropriate information system would be very significant to the organization. However, this is not part of our current research work.

As stated in various places in this report, some of the identified issues or difficulties the project team faced were due to the lack of an effective information system. For example, if a project team intends to collect and document all its project data in one place, it first needs an appropriate database and integrated information system to provide and support the required functions for the database operation. Some other issues reveal the different needs for functions from this kind of integrated information system. Identifying the company's requirements of an integrated information system and proposing an appropriate one that is able to accommodate the project work will be a very valuable research topic.

The second aspect is concerned with the decision-making mechanisms in the distributed team context. Our current research does not address this topic, although this topic remains under-researched in the current literature and is a very important research subject in project management. When we reviewed some exchanged email messages, we found out that the project participants, especially the decision-makers at the central office sometimes mentioned that they could not make a fast decision when they were reviewing requests from the local iPMO. This issue emerged in a variety of different messages related to different management processes such as integration, procurement, materials, etc. However, other messages sent at almost the same time revealed that the decision-makers at the central office were able to make very efficient decisions in directing and instructing the project work executed in the local iPMO environment. An in-depth investigation of decision-making mechanisms in this context would be another interesting research topic.

The third aspect is concerned with the validation of various models proposed in this report. Although our current research reveals that the proposed models can effectively resolve the individual issues and common problems identified from this case study, the validation of those models in a new project environment will be essential to the effective application of them in a broad construction project context. The first step for future research is to validate the proposed models in a project environment very similar to that for this case study. The second step is to validate the proposed models in other project environments with more changed variables.

CHAPTER 7
CONCLUSION

Based on the review and study of the exchanged email messages, this research first identified and established the information flow patterns associated with a construction project executed in an internationally distributed team context. The most important areas, as measured by information flow volume, are communication, integration, procurement, materials and HR.

Considering that volume distribution may not reflect the nature of the topic itself, we then conducted an in-depth investigation of the exchanged messages in order to classify and differentiate the information flows according to topic. A generic information flow model within the distributed context illustrates the classification of all messages into two main categories: one for communication and information requests and another for information sharing. As the first category tended to contain the most interactive communication topics, our research focused on the observation of this category.

The in-depth investigation of the interactive and communicative features of the exchanged message groups revealed that integration, procurement and materials were affected by the most issues and became the most critical processes for the project's execution in the distributed work environment. The various issues related to integration, procurement and materials were observed, identified and documented. The evidence from the identified issues reveals that the common problems affecting all three processes were a lack of well-defined subprocesses, lack of well-defined roles and responsibilities, lack of well-defined information needs and communication requirements, and lack of understanding of issues associated with the various subprocesses.

This report proposes and develops a series of generic models, use case models, and activity diagram models to address various issues and resolve the common problems associated with integration, procurement and materials management. The generic models show the sequence and relationships among various subprocesses for integration, procurement and materials, and the main information sources from which the models were developed. Use case models define, at a high level, the roles and responsibilities of each stakeholder involved with integration, procurement and materials management. The activity diagrams define the procedures and components in more detail, for each subprocess in the management processes in question. The activity diagrams corresponding to each subprocess can serve as effective solutions to address the identified issues and resolve the common problems associated with integration, procurement and materials management.

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APPENDICES

APPENDIX A

IDENTIFIED ISSUES RELATED TO WORK PROCESSING IN INTEGRATION

No.	Date	Identified Issues Related to Work Processing in Integration Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
1	15/02/2005	Piping leak due to low-quality materials and poorly trained installer.	X	X				
2	14/02/2005	Problem due to defective local equipment use; control board was not aware of the executed changes.		X	X	X		
3	13/09/2005	iPMO supervisor was not able to justify the system function due to lack of instructions.	X					
4	10/06/2005	CO had the updated document, but iPMO did not know and was waiting for it.		X			X	
5	01/08/2005	iPMO reported a problem, but CO did not understand due to lack of contextual information.		X	X			
6	31/08/2005	Change requested due to local construction procedure; CO spent a long time evaluating the change request as it had no knowledge of local procedures and products; work was on hold due to the inconclusive instructions.	X	X	X			
7	14/09/2005	CO did not have the complete as-built information for the final drawing.			X	X		X
8	11/11/2005	iPMO and CO had different visions of the importance of as-built information when updating the as-built drawings.				X		X
9	01/12/2005	iPMO requested support in solving an equipment problem, and CO was not able to provide a solution as too many factors were unknown to it.		X		X	X	
10	19/09/2005	A potential quality issue existed due to malfunctioning equipment; it took more than two weeks to find and solve the problem. iPMO thought that the problem was due to some imported equipment, whereas CO thought that the problem stemmed from the local suppliers.	X	X				
11	16/02/2005	Due to many changes, CO mentioned that they did not know which panel should be used to connect a piece of equipment.			X	X		
12	04/02/2005	CO was not able to make a decision due to a lack of information and knowledge of the local project context.		X		X		
13	18/11/2005	CO was not sure if they had the right understanding of a question regarding change control.			X	X		
14	04/10/2005	CO could only guess that one selected solution might be better than another due to its limited knowledge of the actual project work.			X	X		
15	14/07/2005	Roof overflow problem due to heavy rain. The same problem repeated in this project.	X	X	X			

No.	Date	Identified Issues Related to Work Processing in Integration Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
16	10/10/2005	Executed work was not clear to CO.				X		
17	17/11/2005	Drawing version confusion due to numerous transfers and updates.		X	X	X		X
18	25/11/2005	CO requested more precise information for updating the as-built drawings; people had to communicate and interact a lot to get the necessary information.			X	X		X
19	10/11/2005	Message receiver thought that message sender did not provide complete information to reflect the reality of the construction work.				X		X
20	11/11/2005	One important change was not recorded and was not clear to CO.			X	X		X
21	10/11/2005	An important change was not recorded for the as-built drawing; CO asked iPMO to provide the as-built information. As this was not recorded, iPMO had to recall and check the actual work.			X	X		X
22	11/11/2005	The same problem as No. 21.			X	X		X
23	01/03/2005	Major change required satisfying the local customer's needs; the team had to do system reengineering work during construction.		X	X			
24	13/04/2005	Potential rework due to a request from CO after their review of the executed work.	X	X				
25	25/03/2005	No well-defined specifications for the locally supplied equipment.	X					
26	21/02/2005	Wrong work due to confusing instructions from different document versions.	X					
27	17/08/2005	iPMO did not have the information to identify some malfunctioning equipment.	X	X				
28	15/08/2005	One new technical solution due to a change request had to be validated.			X			
29	13/05/2005	iPMO did not have the instructions for an item of equipment to be installed.	X					
30	22/03/2005	iPMO did not have the information to present to the local inspector for the local inspection procedure.	X	X			X	
31	10/06/2005	Information missing on the drawings for a piece of equipment to be installed; the location of the equipment changed a few times, but the discussion process was not clear to CO.	X		X	X		
32	31/10/2005	iPMO did not have the information to make the final document.				X		X
33	03/03/2005	The executed work due to a change was not recorded in the drawing.		X	X	X		
34	20/01/2005	iPMO did not have the instructions for work execution.	X					
35	09/06/2005	Communicators mentioned that they would keep the discussion and conclusion of the approved change in mind.			X	X		

No.	Date	Identified Issues Related to Work Processing in Integration Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
36	27/01/2005	Work pending due to local payment issues.			X	X		
37	14/03/2005	CO requested information on some executed work for verification.		X		X		
38	25/03/2005	CO did not understand why a planned job had not been executed yet.		X	X	X		
39	03/10/2005	A major change was requested by the local customer; iPMO passed this request on to CO; CO needed more information for review and evaluation.			X	X		
40	16/02/2005	Rework discussion due to the wrong information in the instructions.	X	X	X			
41	25/10/2005	Requested change due to work pending while awaiting a local payment.			X	X		
42	04/10/2005	A message from CO on an approved change included wording such as "SEEMS ACCEPTABLE, HOPE NO PROBLEM, GUESS WE CAN LIVE WITH IT."			X	X		
43	05/10/2005	Planned work pending awaiting discussion of the requested change control procedure.		X	X			
44	22/09/2005	CO could not judge and justify a potential conflict between different items of installed equipment due to a requested change.		X	X	X		
45	10/03/2005	Confusion due to different instruction documents; work was on hold awaiting clarification of the specifications.	X	X	X			
46	04/04/2005	CO's wording in evaluating the project work included "SEEM, GUESS," etc.		X		X		X
47	16/11/2005	Local customer did not understand the importance of maintaining the right operation status as per design requirements.					X	X
48	05/02/2005	A major equipment malfunction due to new local conditions.		X	X	X		
49	07/06/2005	A distributed discussion on the change control procedure took 4 communication loops and more than one week to conclude.			X	X		
50	13/06/2005	One participant did not receive the project report and other project information due to Outlook's volume limitations.				X		
51	28/02/2005	CO did not have the relevant information when reviewing executed work.		X		X		
52	17/08/2005	iPMO proposed a local solution for a requested change; CO did not understand many details of the local product, local procedure and materials use.		X	X	X		
53	10/03/2005	CO did not understand some executed work; requested change was not recorded; iPMO could not explain the situation very clearly by email; an urgent phone call was required.		X	X	X		

No.	Date	Identified Issues Related to Work Processing in Integration Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
54	26/08/2005	Wrong local pricing information provided by iPMO (in error) led to an inappropriate evaluation and selection of the option at CO.		X		X		
55	18/05/2005	Installation as per design did not fit local needs; this led to a change request; CO did not have the necessary information to evaluate the change request.	X	X	X	X		
56	16/11/2005	Planned work on an approved change was on hold pending the local payment.			X	X		
57	06/10/2005	iPMO did not have the complete drawings; the drawing transfer was not recorded.	X	X				
58	15/11/2005	Message receiver did not understand a message from the sender; This led to more discussions to understand the questions and provide answers.		X		X		
59	23/08/2005	The recipient responded to the message after more than two weeks; iPMO requested missing information on an installation job.	X	X				
60	11/11/2005	iPMO communicated with CO about the as-built information.			X	X		X
61	11/11/2005	The same as No. 60.			X	X		X
62	11/11/2005	The same as No. 60.			X	X		X

Note:
A. Prepare and instruct project work; B. Execute and verify project work; C. Change order and control; D. Document and report project work; E. Do operational testing; F. Deliver and close project

APPENDIX B

IDENTIFIED ISSUES RELATED TO WORK PROCESSING IN PROCUREMENT

No.	Date	Identified Issues Related to Work Processing in Procurement Management	Issues Resolved in Process Categories				
			A	B	C	D	E
1	19/08/2005	A planned imported material was not delivered to the project site; separate delivery was too expensive due to transportation; iPMO searched for a local option, but did not have clear specifications.	X	X			
2	13/10/2005	A required component was not installed on locally ordered equipment due to confusion about the order requirements and specifications.	X	X	X	X	
3	02/06/2005	As requested by CO, iPMO contacted some local suppliers asking for proposals, but many details of the specifications were not clearly defined.	X	X			
4	31/08/2005	A new material was required due to a change; too expensive to send it from CO; iPMO wanted to check the local option but did not know the requirements and specifications or the local market conditions and local suppliers.	X				
5	14/03/2005	The price for an outsourcing service was not clearly concluded; iPMO found it too expensive when the service provider executed the work.		X	X		
6	09/03/2005	iPMO had to confirm an order with a local supplier the next day, but the technical capacities had not been concluded yet with CO. iPMO sent a message for confirmation request; But CO forgot to answer.	X	X			
7	17/02/2005	CO requested iPMO to search a local option for equipment; But iPMO was not clear about many details of the requirement and specifications.	X				
8	25/08/2005	iPMO had to request the proposal from a local supplier the next morning; they found that one of the specifications was wrong on the PO request document.	X	X			
9	06/09/2005	CO used the wording "I GUESS THAT IT MIGHT BE OK" for a specifications definition.	X	X			
10	28/09/2005	A confirmed PO with a local supplier could not be executed due to incorrect pricing information on the contract.		X	X	X	
11	01/11/2005	iPMO found out that a locally made option was not applicable only when it had completed the procedure. They had to rethink the two options: one via PO and another locally made.	X	X			

No.	Date	Identified Issues Related to Work Processing in Procurement Management	Issues Resolved in Process Categories				
			A	B	C	D	E
12	16/08/2005	The requirements for an item of equipment were not well defined; iPMO had a few meetings and discussions on the proposal; finally this equipment was removed from the project scope.	X	X			
13	01/10/2005	CO was not able to evaluate local proposals; they mentioned that "IT SOUNDS VERY CHEAP, BUT WE DO NOT KNOW WHAT IS INCLUDED."		X	X		
14	16/02/2005	CO had difficulties justifying quality when selecting local suppliers.			X		
15	14/03/2005	CO could not find the information on the decision regarding the quality of local orders; They were still questioning the quantity during the order delivery.		X	X		X
16	13/05/2005	Locally ordered bulk materials were inadequate to complete the planned work even though the quantity was based on the calculations from the design.	X	X	X	X	X
17	07/03/2005	iPMO asked a local supplier to provide a proposal, while at the same time CO and iPMO were discussing important data for the specifications.	X				
18	14/03/2005	CO commented "SEEMS OK" about a local outsourcing service.	X				
19	13/10/2005	CO asked iPMO to check a local option, but did not provide a detailed description of the items to be searched for.	X				
20	09/03/2005	Due to the measurement system difference, iPMO had difficulties finding imported parts on the local market.	X				
21	26/08/2005	An error in pricing information from iPMO misled CO in evaluating a local proposal.			X		
22	24/02/2005	CO did not know how to justify the locally made and locally bought options.	X				
23	02/03/2005	CO asked for a local material, but did not provide the clear specifications.	X				
24	31/05/2005	CO found it difficult to judge local product quality.		X	X		
25	28/01/2005	iPMO planned to buy a material locally; at the same time, iPMO and CO were discussing budgeting and safety issues.	X	X			
26	13/03/2005	iPMO needed to obtain a special tool from a local source, but did not have the specifications.	X				
27	02/11/2005	iPMO received a request from CO to search for a product, but there was no information on its technical capacity.	X				
28	16/02/2005	CO asked iPMO to search for a product, but iPMO did not understand the requirements.	X				

No.	Date	Identified Issues Related to Work Processing in Procurement Management	Issues Resolved in Process Categories				
			A	B	C	D	E
29	23/11/2005	iPMO did not have precise information to show a local supplier; the pricing information from the local supplier was not detailed enough for CO.	X	X	X		
30	18/08/2005	iPMO was discussing a proposal with a local supplier but it did not have the detailed specifications and requirements.	X				
31	21/09/2005	A technical question was still under discussion between iPMO and CO when the purchase order was confirmed with a local supplier.	X	X			
32	15/02/2005	iPMO did not have a general list for local buying.	X				

Note:
A. Prepare PO document; B. Request for proposals; C. Select suppliers; D. PO administration and follow up; E. Order delivery and reception

APPENDIX C

IDENTIFIED ISSUES RELATED TO WORK PROCESSING IN MATERIALS

No.	Date	Identified Issues Related to Work Processing in Materials Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
1	25/04/2005	Hard to find local replacements for easily broken parts on imported equipment; no spares for these easily damaged parts; no clear specifications for these parts.	X	X			X	
2	01/04/2005	CO did not have clear information on the materials stocked on the project site; iPMO had to check the inventory and find the materials to determine the answer.			X		X	
3	16/02/2005	An important piece of equipment was not available during the system installation; it was indicated on the imported equipment list, but in fact it had been left in stock at the CO; the work was on hold while the team waited for the urgent delivery from CO.		X	X	X	X	
4	07/03/2005	The same as No. 1.		X	X	X	X	
5	22/03/2005	iPMO did not have clear information on the imported materials delivery schedule.		X				
6	29/06/2005	iPMO requested instructions on how to assemble certain materials; CO said that it had already sent it; planned work was on hold for this reason.		X	X		X	
7	08/04/2005	There were not enough imported materials to complete the planned work; iPMO only realized this when executing the work, which was delayed while waiting for more materials to be delivered.	X	X	X	X	X	
8	15/11/2005	A requested change involved a change in materials use; the delivered materials for this project were installed. In the end, iPMO found two leftovers from the stock for the other project, but no specifications.			X	X		X
9	17/03/2005	There were only enough imported materials to complete part of the planned work; the size of the materials did not fit local needs; there was no link between materials used and materials in inventory.	X	X	X	X	X	X
10	16/06/2005	There were no instructions for an item of imported equipment; work was on hold for this reason.		X	X		X	

No.	Date	Identified Issues Related to Work Processing in Materials Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
11	14/10/2005	One instruction document did not contain the information needed for the installed models.		X			X	
12	29/08/2005	The quantity and size of received materials did not fit the needs of the planned work; there was no clear connection between materials received and project work; missing or incorrectly sent materials were only discovered when doing the work.		X	X	X	X	
13	17/10/2005	CO did not have clear information on the materials stocked on the project site; iPMO had to check the inventory and find the materials to determine the answer.			X			
14	08/02/2005	A motor for an imported machine was missing; no indication on the imported equipment list; the absence was only found when the machine was being installed.		X	X	X	X	
15	01/08/2005	An unplanned piece of equipment was required because of local needs; this led to a change request affecting equipment.	X					X
16	01/04/2005	An unanswered change request led to uncertainty as to how to use materials.						X
17	12/10/2005	CO did not know how much material the executed work had used; iPMO found that there were not enough materials during the execution of project work, even though the quantity indicated on the imported materials packing list was adequate.		X	X	X	X	
18	03/06/2005	iPMO did not know a wrongly sized material would be modified as per CO's requirements.		X			X	X
19	16/08/2005	Following the subject of No. 17, CO did not know the results of the modified work done by iPMO.						X
20	03/05/2005	iPMO was not clear about the schedule for a materials delivery on a packing list.		X				
21	07/03/2005	It was not clear to iPMO whether some planned work would be done using imported materials; iPMO and CO had different understandings of the timing of the work.	X			X		
22	23/08/2005	An item of imported equipment did not fit local needs.	X	X			X	X
23	10/08/2005	There were no spares for easily broken parts; the ones received were the wrong size due to confusion concerning the model.	X	X		X		

No.	Date	Identified Issues Related to Work Processing in Materials Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
24	19/10/2005	iPMO could not find the information on a material in the files.		X	X			
25	30/05/2005	A piece of equipment needed to be assembled with received materials, but there was no information on how to do so; iPMO was not clear on how many materials would be required to complete various jobs using the same kinds of materials.		X	X	X	X	
26	22/02/2005	An important item of equipment was not available when needed for the project work.		X	X		X	X
27	24/02/2005	CO asked if the site inventory had a certain list of materials; iPMO had to physically check the inventory to find the answer.			X			
28	18/11/2005	An imported material was required due to a change; by chance iPMO found two leftovers from another project; no specifications on the equipment; CO had no record of it.		X	X	X	X	X
29	23/08/2005	Another imported material was required due to a change; only by chance was the received material enough to cover this.	X	X	X	X		X
30	15/08/2005	An imported machine did not work well; this triggered discussions concerning a solution.		X				X
31	24/08/2005	A locally needed material was not on the materials plan; iPMO asked CO to send it while it was already doing the job.	X		X	X	X	
32	01/08/2005	A local construction procedure triggered the use of a local material; iPMO had no experience with using the material; the safety of the material was a potential issue.						X
33	06/06/2005	iPMO found imported materials unavailable when executing the work and checked with CO; CO answered that the materials had been delivered a long time ago. Materials missing; no records to track them.		X	X		X	
34	06/04/2005	iPMO did not have the packing list and shipping information for an imported materials container.		X			X	

No.	Date	Identified Issues Related to Work Processing in Materials Management	Issues Resolved in Process Categories					
			A	B	C	D	E	F
35	19/05/2005	iPMO received a large machine and was not clear about its application; no clear indication on the packing list. When iPMO checked with CO, they finally understood that it was for another project.	X	X			X	
36	14/06/2005	Some imported materials faced very complicated inspection procedures. Planned work could not be executed for this reason.	X	X				
37	19/01/2005	iPMO was not clear about the use of two pieces of imported equipment; no instructions or indications.		X			X	
38	23/03/2005	iPMO did not have the instructions for an item of imported equipment; CO did not have the information on a locally used material.		X			X	X
39	20/05/2005	iPMO received some imported material from CO, but did not know where to install it; no instructions to follow.		X			X	

Note:
A. Materials planning; B. Acquire materials; C. Stock materials; D. Issue materials ; E. Materials verification; F. Materials control

APPENDIX D

PROJECT MANAGEMENT PROCESSES AND DEFINITION (PMI, 2004, 2007)

Code	Project Management Process	Definition
P1	4.1 Develop Project Charter	The process of developing the project charter that formally authorizes a project.
P2	4.2 Develop Preliminary Project Scope	The process of developing the preliminary project scope statement that provides a high-level scope narrative.
P3	4.3 Develop Project Management Plan	The process of documenting the actions necessary to define, prepare, integrate, and coordinate all subsidiary plans into a project management plan.
P4	4.4 Direct and Manage Project Execution	The process of executing the work defined in the project management plan to achieve the project's requirements defined in the project scope statement.
P5	4.5 Monitor and Control Project Work	The process of monitoring and controlling the processes required to initiate, plan, execute, and close a project to meet the performance objectives defined in the project management plan and project scope statement.
P6	4.6 Integrated Change Control	The process of reviewing all change requests, approving changes and controlling changes to deliverables and organizational process assets.
P7	4.7 Close Project	The process of finalizing all activities across all of the project progress groups to formally close the project or phase.
P8	5.1 Scope Planning	The process of creating a project scope management plan.
P9	5.2 Scope Definition	The process of developing a detailed project scope statement as the basis for future project decisions.
P10	5.3 Create WBS	The process of subdividing the major project deliverables and project work into smaller, more manageable components.
P11	5.4 Scope Verification	The process of formalizing acceptance of the completed project deliverables.
P12	5.5 Scope Control	The process of controlling changes to the project scope.
P13	6.1 Activity Definition	The process of identifying the specific scheduled activities that need to be performed to produce various project deliverables.
P14	6.2 Activity Sequencing	The process of identifying and documenting dependencies among scheduled activities.
P15	6.3 Activity Resource Estimating	The process of estimating the types and quantities of resources required to perform each scheduled activity.
P16	6.4 Activity Duration Estimating	The process of estimating the number of work periods that will be needed to complete individual scheduled activities.
P17	6.5 Schedule Development	The process of analyzing scheduled activity sequences, scheduled activity durations, resource requirements, and schedule constraints to create the project schedule.

Code	Project Management Process	Definition
P18	6.6 Schedule Control	The process of controlling changes to the project schedule.
P19	7.1 Cost Estimating	The process of developing an approximation of the cost of the resources needed to complete project activities.
P20	7.2 Cost Budgeting	The process of aggregating the estimated costs of individual activities or work packages to establish a cost baseline.
P21	7.3 Cost Control	The process of influencing the factors that create variances, and controlling changes to the project budget.
P22	8.1 Quality Planning	The process of identifying which quality standards are relevant to the project and determining how to satisfy them.
P23	8.2 Perform Quality Assurance	The process of applying the planned, systematic quality activities to ensure that the project employs all processes needed to meet requirements.
P24	8.3 Perform Quality Control	The process of monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance.
P25	9.1 Human Resource Planning	The process of identifying and documenting project roles, responsibilities and reporting relationships, as well as creating the staffing management plan.
P26	9.2 Acquire Project Team	The process of obtaining the human resources needed to complete the project.
P27	9.3 Develop Project Team	The process of improving the competencies and interaction of team members to enhance project performance.
P28	9.4 Manage Project Team	The process of tracking team member performance, providing feedback, resolving issues, and coordinating changes to enhance project performance.
P29	10.1 Communication Planning	The process of determining the information and communications needs of the project stakeholders.
P30	10.2 Information Distribution	The process of making needed information available to project stakeholders in a timely manner.
P31	10.3 Performance Reporting	The process of collecting and distributing performance information. This includes status reporting, progress measurement and forecasting.
P32	10.4 Manage Stakeholders	The process of managing communications to satisfy the requirements of, and resolve issues with, project stakeholders.
P33	11.1 Risk Management Planning	The process of deciding how to approach, plan, and execute risk management activities for a project.
P34	11.2 Risk Identification	The process of determining which risks might affect the project and documenting their characteristics.
P35	11.3 Qualitative Risk Analysis	The process of prioritizing risks for subsequent further analysis or action by assessing and combining their probability of assurance and impact.

Code	Project Management Process	Definition
P36	11.4 Quantitative Risk Analysis	The process of numerically analyzing the effect on overall project objectives of identified risks.
P37	11.5 Risk Response Planning	The process of developing options and actions to enhance opportunities and to reduce threats to project objectives.
P38	11.6 Risk Monitoring and Control	The process of tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.
P39	12.1 Plan Purchase and Acquisitions	The process of determining what to purchase or acquire, and determining when and how to do so.
P40	12.2 Plan Contracting	The process of documenting the products, services, and results requirements and identifying potential sellers.
P41	12.3 Request Seller Response	The process of obtaining information, quotations, bids, offers, or proposals, as appropriate.
P42	12.4 Select Sellers	The process of reviewing offers, choosing from among potential sellers, and negotiating a written contract with a seller.
P43	12.5 Contract Administration	The process of managing the contract and the relationship between buyer and seller, reviewing and documenting how a seller is performing or has performed to establish required corrective actions and provide a basis for future relationships with the seller, managing contract related changes and, when appropriate, managing the contractual relationship with the outside buyer of the project.
P44	12.6 Contract Closure	The process of completing and settling the contract, including resolution of any open items and closing each contract.
P45	13.1 Perform Safety Planning	The process of determining how to approach, plan, and execute the requirements for project safety management, which safety standards are relevant to the project and determining how to satisfy them.
P46	13.2 Perform Safety Assurance	The process of applying safety activities, determining their effectiveness, and evaluating the results of safety management.
P47	13.3 Perform Safety Control	The process of determining and applying measures for monitoring project results and identifying ways to eliminate causes of unsatisfactory performance.
P48	14.1 Perform Environmental Planning	The process of determining how to approach, plan, and execute the requirements for project environmental management; identifying the characteristics of the environment surrounding the construction site and determining which environmental standards are relevant to the project.

Code	Project Management Process	Definition
P49	14.2 Perform Environmental Assurance	The process of applying the planned, systematic environmental activities to ensure that the project employs all processes needed to meet environmental requirements.
P50	14.3 Perform Environmental Control	The process of determining and applying measures for monitoring the achievement of specific project results throughout the project to determine whether they comply with the requirements and identifying unsatisfactory performance.
P51	15.1 Financial Planning	The process of identifying key financial issues to be addressed and assigning project roles, responsibilities, and reporting relationships.
P52	15.2 Financial Control	The process of monitoring key influences identified in Financial Planning and taking corrective measures when negative trends are recognized.
P53	15.3 Administration and Record	The process of designing and maintaining a financial information storage/retrieval database to enable financial control to proceed smoothly.
P54	16.1 Claim Identification	Identification of a claim starts with sufficient knowledge of the project scope and contract requirements, which leads to an awareness that some activity may involve a change in scope or the contract.
P55	16.2 Claim Quantification	The process of quantifying the potential claim in terms of additional compensation, a time extension to the contract completion or both.
P56	16.3 Claim Prevention	The process of keeping issues from arising which could develop into claims. The perfect, well-scoped, risk-allocated, and well-executed contract is less likely to result in any claims.
P57	16.4 Claim Resolution	The process of settling claim issues soon and at the lowest practicable point in the organization.