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**PROJECT SCHEDULING TO MAXIMIZE POSITIVE IMPACTS OF
RECONSTRUCTION OPERATIONS**

THESIS

Andrew D. Chaney, Captain, USAF

AFIT/GOR/ENS/09-03

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY**

Wright-Patterson Air Force Base, Ohio

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AFIT/GOR/ENS/09-03

**PROJECT SCHEDULING TO MAXIMIZE POSITIVE
IMPACTS OF RECONSTRUCTION OPERATIONS**

THESIS

Presented to the Faculty
Department of Operational Sciences
Graduate School of Engineering and Management
Air Force Institute of Technology
Air University
Air Education and Training Command
in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Operations Research

Andrew D. Chaney, B.S.
Captain, USAF

March 2009

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Abstract

Since the decline of the Cold War, the risk of major conflict between powerful industrialized nations has significantly decreased. Insecurity in the twenty-first century is forecast to arise rather from the debris of imploding states. Such situations may require intervention — military or otherwise — by concerned states, and the frequency with which these interventions occur is increasing. To meet this new operational challenge, the US military must adapt its planning procedures to account for Security, Stabilization, Transition, and Reconstruction Operations (SSTRO).

This research develops a project scheduling based framework for post-conflict reconstruction that prioritizes and schedules reconstruction activities in such a way as to maximize the positive impacts during the initial phase of SSTRO. Specifically, this research proposes to build on the Multimode Resource Constrained Project Scheduling Problem with Generalized Precedence Relations (MM-RCPSP-GPR) using goal programming to maximize the reconstruction operations' positive impact to the local population.

This MM-RCPSP-GPR variant is applied to a notional example to illustrate its potential use in post-conflict SSTRO.

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Maj. Kevin Calhoun provided invaluable assistance in translating the problem formulation to LINGO.

And I cannot give enough thanks to my wife, my family, my friends, and my Savior.

Andrew D. Chaney

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PROJECT SCHEDULING TO MAXIMIZE POSITIVE IMPACTS OF RECONSTRUCTION OPERATIONS

I. Introduction

To truly achieve victory as Clausewitz defined it — to attain a political objective — the United States needs a military whose ability to kick down the door is matched by its ability to clean up the mess and even rebuild the house afterward.

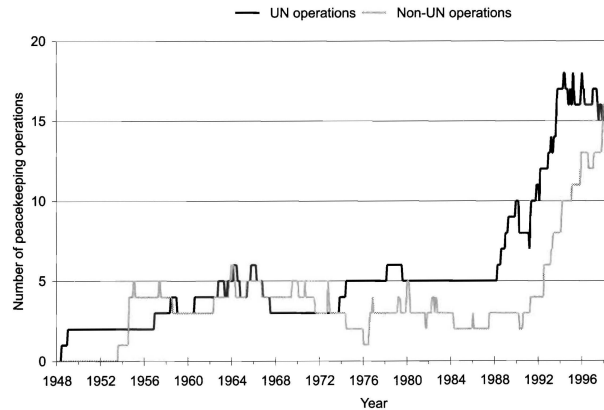
—Robert M. Gates, Secretary of Defense, 2009

1.1 Background

Since the decline of the Cold War, the risk of major conflict between powerful industrialized nations has significantly decreased [Rice 2005]. Insecurity in the twenty-first century is forecast to arise instead from the “debris of imploding” states [Haims, Gompert, Treverton, and Stearns 2008].

Failed states present a variety of dangers: religious and ethnic violence; trafficking of drugs, weapons, blood diamonds, and humans; transnational crime and piracy; uncontrolled territory, borders, and waters; terrorist breeding grounds and sanctuaries; refugee overflows; communicable diseases; environmental degradation; warlords and stateless armies. [Haims *et al.* 2008:ix].

Modern diplomacy and statecraft are based on the assumption that the participants are sovereign states able to manage their own internal affairs and address threats arising within their borders. This assumption is no longer valid. “[T]he greatest threats to our security are defined more by the dynamics within weak and failing states than by the borders between strong and aggressive ones” [Rice 2005].



[Heldt 2008:11]

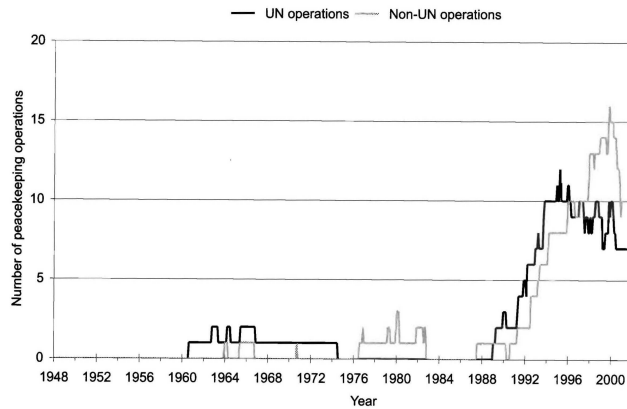
Figure 1 Trends in Peacekeeping Operations, 1948 - 2005

In light of modern advances in travel and communication, it is now possible for threats arising in weak states to affect the entire global community [*ibid.*].

According to the US State Department’s Office of the Coordinator for Reconstruction and Stabilization (S/CRS), failed and failing states present both a humanitarian challenge and a national security challenge to the major industrialized nations of the world [DoS 2004]. Such situations may require intervention — often military intervention — by concerned states, and the frequency with which these interventions occur is increasing [Heldt 2008]. Since 1988 there has been a dramatic upswing in the number of active peacekeeping operations. In 1988, there were five UN peacekeeping operations and three non-UN peacekeeping operations; in 2005, there were 15 UN and 14 non-UN peacekeeping operations active (Figure 1).

Even more dramatic is the increase in peacekeeping operations to control intrastate state conflict: prior to 1990, there were never more than three simultaneous peacekeeping operations to control intrastate conflict; in 2005, there were 21 (Figure 2).

US policy has acknowledged the growing importance of Stabilization, Security, Transition, and Reconstruction Operations (SSTRO) to US national interests. In



[Heldt 2008:13]

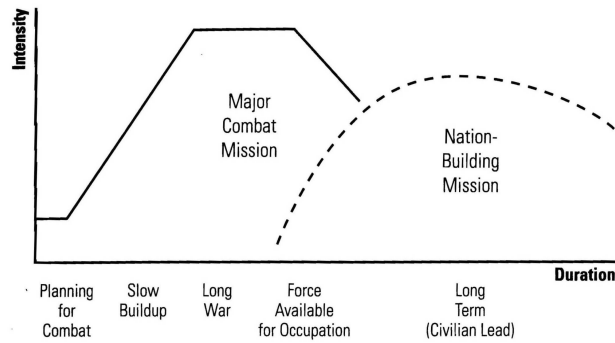
Figure 2 Trends in Peacekeeping Operations, Intrastate Conflicts, 1948-2005

2005, President Bush issued National Security Presidential Directive 44 (NSPD-44) formally establishing the importance of strong SSTR capabilities to US Government interests. NSPD-44 directs the Department of State to “coordinate and lead integrated United States Government efforts . . . to prepare, plan for, and conduct stabilization and reconstruction activities” [NSPD-44:2].

The Department of Defense (DoD) has also begun to emphasize stabilization operations: DoD Directive 3000.05 (also released in 2005) establishes stability operations as a core U.S. military mission that the DoD must be prepared to conduct and support.

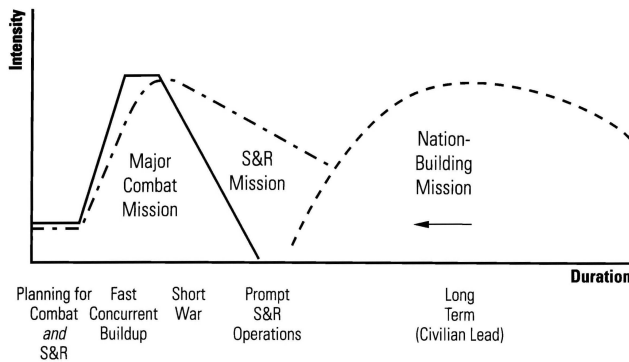
To meet this new doctrinal requirement, the US military is adapting its planning procedures to account for SSTRO. In the past, conflicts were protracted and required large numbers of troops in the theater. This meant that planners were able to develop SSTR plans as the conflict progressed and that a large number of troops were available for occupation at the end of the conflict (Figure 3) [Binnendijk and Johnson 2004:xiv].

Binnendijk and Johnson, in a report for the Center for Technology and National Security Policy at the National Defense University, assert that, in the US military’s new strategy of rapid, decisive action, less time is available for planning SSTRO, and



[Binnendijk and Johnson 2004:xiv]

Figure 3 Historical Pattern of Combat and S&R Missions



[Binnendijk and Johnson 2004:xvi]

Figure 4 Transformed Stabilization & Reconstruction Capability

that reliance on near-real- and real-time intelligence, surveillance, and reconnaissance and on Special Forces as force multipliers means there are far fewer troops in the theater at the end of combat operations. Military planning must evolve to effectively prepare for SSTRO in this new environment — planning for combat and SSTRO operations must occur concurrently, and SSTRO should be ready to begin as combat operations are ending (Figure 4) [2004:xvi].

Further, the capability for SSTRO planning is not limited only to reconstruction after a US or allied intervention, but will also be applicable in the aftermath of any conflict or natural or man-made disaster [*ibid.*:xv-xvi].

Based on this need for robust planning capabilities for SSTRO, the National Science and Technology Council (NSTC) [2008:15] recommends further research to

formulate strategies to assist in post-conflict reconstruction of regional and local infrastructures — specifically in the areas of developing techniques to manage risk and maximize the impact of infrastructure reconstruction on the population; developing tools to facilitate prioritization and management of reconstruction efforts; and providing means of effecting local participation in the reconstruction activities.

Further, the recently released *U.S. Government Counterinsurgency Guide* — signed by the Secretaries of State and Defense and the Administrator of USAID — acknowledges the role of essential services and economic considerations in stabilization operations: stating that COIN operations seek

to provide essential services and stimulate long term economic growth, thereby generating confidence in the government while at the same time reducing the pool of frustrated, unemployed young men and women from which insurgents can readily recruit [USGICI 2009:3].

1.2 Problem Statement and Approach

As major combat operations wind down, the military will need to act rapidly to reestablish basic essential services and rebuild the local infrastructure. Roads and bridges, local power stations, water pumping stations, and so on, may have been damaged or destroyed by combat or neglect — they may, in fact, have been legitimately targeted during combat operations. At the same time, it is likely that the local economy will have stagnated, and the stabilizing force will also need to facilitate the restarting of normal economic activities. A natural solution to both of these problems is to employ, as much as possible, the indigenous workforce to effect repairs to the local and regional infrastructure.

Pursuant to the NSTC’s recommendations, this research develops a *project scheduling* framework for post-conflict reconstruction that schedules reconstruction tasks in such a way as to maximize the positive impact to the local economy during the initial phase of SSTR operations. Specifically, this research proposes to build on

the *Multimode Resource Constrained Project Scheduling Problem* with goal programming to maximize the reconstruction activities' positive impact to local population's economic welfare.

1.3 Thesis Organization

This introduction has developed the relevance of this research effort and outlined its approach. Chapter II reviews the current literature in the fields of SSTRO, social welfare, resource constrained project scheduling, and goal programming. Chapter III develops the model that this research uses to solve the RCPSP goal program for post-conflict reconstruction. In Chapter IV, a notional post-conflict reconstruction effort is used to illustrate the application of the model. Chapter V contains the conclusions and suggestions for future research.

II. Relevant Literature

2.1 Introduction

This chapter provides an overview of the literature relevant to the development of a post-conflict reconstruction program model. Section 2.2 introduces literature pertaining to strategies for SSTR Operations including US Government policy, military doctrine, and guidance from humanitarian agencies. Section 2.3 surveys the literature pertaining to measuring socio-economic welfare. Section 2.4 reviews the current literature on resource constrained project scheduling, and Section 2.5 introduces the concept of goal programming.

2.2 SSTR Operations Literature

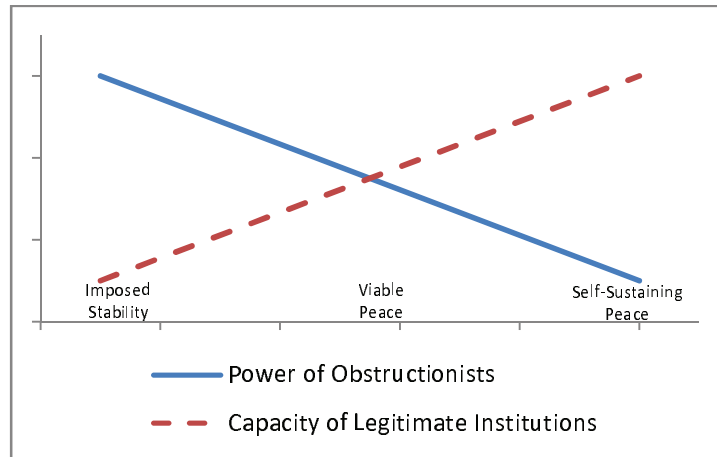
2.2.1 Strategies for SSTR Operations

Covey, Dziedzic, and Hawley's *The Quest for Viable Peace* emphasizes the importance of "conflict transformation" — transitioning from a conflict to a viable peace and then to self-sustaining peace [Covey *et al.* 2005:15]. As Figure 5 shows, as legitimate power structures increase in strength, obstructionist powers' influence wanes.

They further develop ten building blocks for a successful intervention [Covey *et al.* 2005:49-57].

Compelling Justification for Intervention. Transformation operations may require a long-term commitment by the nations involved. The justification for the intervention must be strong enough to hold for the duration.

Backing of Influential Regional Powers. Local powers often have close ties with one or more of the factions and can facilitate or frustrate the peace process.



[Covey *et al.* 2005:15]

Figure 5 Viable Peace: The Turning Point in Conflict Transformation

Achievable Political Solution. A mutually acceptable political solution can channel the factions' competition for power into political rather than violent means.

Operational Assistance by Neighboring States. If neighboring countries have ties to one of the factions, they are unlikely to remain uninvolved in the conflict.

Containment of Transitional Nonstate Threats. Transnational threats can be decisive actors in regions with weak or failing governments. As the stabilization process encroaches on their powerbase, they may seek to obstruct the process.

An Empowering Security Council Resolution. A Security Council resolution provides legitimacy and resources to an intervention.

Acceptable Military Role. Careful coordination of military and civilian roles is necessary for the success of the intervention.

Effective Demobilization of Armed Groups. The demobilization of armed groups is necessary; however, the intervening powers must be able to guarantee safety and economic opportunity for the recently disbanded fighting forces.

Rule of Law: Police, Justice, Penal System, and Applicable Law. The intervening powers often have to supplant the entire justice system in a destabi-

lized region. The former system may have been nonfunctional or dysfunctional, acting as a tool of oppression or economic advancement for a select few. Significant effort and investment may be required to restore the people's trust.

Legitimate Political Economy. People in the destabilized region must have access to a legitimate economy to provide for basic necessities and a legitimate political outlet to provide a voice in the local government.

Ghani and Lockhart derive a model of state sovereignty based on the fulfillment of certain obligations. They list ten functions of the state [2008:124-166]:

Rule of Law The most important function of the state is making and enforcing laws. Laws are the "glue" that hold all the disparate aspects of the state, the economy, and society together. Each of the state's functions is defined by rules enacted as law.

All societies are host to tensions and disagreements: the difference lies in how these disputes are settled: through the process of law or outside it. This is the difference between the civil disobedience of Gandhi and Dr. King and revolutionary movements such as the communist revolutions of Cuba and Russia. When policy change can occur within the system and a strong judiciary can expose and prosecute corruption, stakeholders are more likely to realize their goals through the formal system rather than seeking a solution outside it [*ibid.*:125].

A Monopoly on the Legitimate Means of Violence A monopoly on the legitimate exercise of force has two important effects. First, it guarantees freedom of movement for the population, and second, it guarantees property rights and ensures that transactions are governed by rules rather than force [*ibid.*:129-130].

Administrative Control Administrative control of the government should be handled through a body of openly-recruited professionals accountable to the cit-

izenry [*ibid.*:131]. Entry into government service should be transparent and meritocratic. While there is significant variation between countries, one common trait of successful states is a strong uniformity of administrative rules. This standardization of practice leads to predictability which leads to trust in an impartial government and to an environment suitable for economic growth [*ibid.*:132].

Sound Management of Public Finances Sound management of public finances is critical to realization of public goals. “[T]he discipline of preparation, implementation, and alteration of budgets allows the translation of public goals into measurable programs and projects” [*ibid.*:136].

Investments in Human Capital Economic growth depends on an educated and healthy population. Recent shifts in the private sector emphasize autonomy and creativity rather than rigid discipline — such a system requires educated, thinking workers. A state which does not invest in public education will not be competitive in the global economy [*ibid.*:140-141]. Of equal importance is the provision of health services. Without investment in public health and education, the middle class cannot exist [*ibid.*:141].

Creation of Citizenship Rights Citizenship rights that cut across sex, ethnicity, race, class, and religion are critical to stability. Egalitarian social policy helps unify a state [*ibid.*:144]. Egalitarian social policy transforms a state into “a community of mutual rights and obligations, where each citizen has certain responsibilities vis-à-vis other citizens” [*ibid.*:145]. In weak states, the divisions between population groups are broadened and can result in intergroup rivalries—sometimes to the extent of ethnic cleansing and genocide [*ibid.*:146].

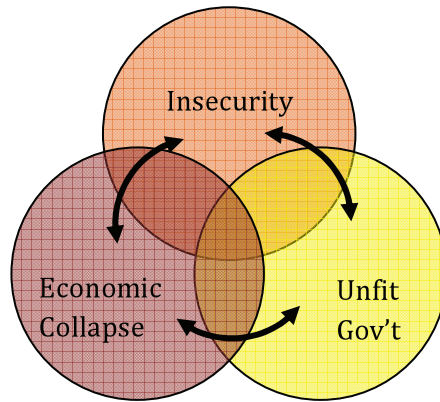
Provision of Infrastructure Services The provision of infrastructure services encompasses transportation, power, water, communications, and pipelines, and it facilitates the state’s provision of security, administration, investment in human capital, and the conditions for a strong market [*ibid.*:147]. Public funding

of infrastructure is a key trait of stable, industrialized nations. The development of transportation infrastructure allows once-isolated markets to be connected and makes the flow of goods and services more predictable. [*ibid.*:148]. This development paves the way for the formation of a strong market. When infrastructure is lacking, inequalities and exclusions persist—particularly in the area of health: the poorer segments of the populace may not have access to sewage systems, clean water, or basic health services [*ibid.*:148].

Formation of a Market Stable states facilitate a strong market by (1) setting and enforcing rules on commercial transactions; (2) supporting private enterprise; and (3) interceding when the market fails. The state can impose significant costs on the market, but the market cannot function without the security, rule of law, education, *etc.* provided by the state [*ibid.*:149-150].

Two models of state support for the market compete. The first allows only indirect support for the market through the other nine functions of the state. The second allows the formation of direct alliances with private-sector entities, protectionist tariff strategies, and government policies to encourage the expansion of particular industries [*ibid.*:151]. Neither model has been proven more effective; the question is not state vs. market but deciding on an allocation of tasks between them to establish a framework to allow the growth of prosperity.

Management of Public Assets Typical budget analysis counts only a state's financial assets; however, a state's capital does not comprise only money. It also includes physical assets — land, equipment, buildings — natural capital — forests, rivers, minerals — and intangible assets such as licensing rights. Of the activities relating to these public assets, the management of land and water rights, the sustainable use of natural capital (including the preservation of the environment), and the licensing of commercial activities are particularly important for a state [*ibid.*:156].



[Haims, *et al.* 2008]

Figure 6 The Cycle Characterizing Failed States

Effective Public Borrowing Public borrowing is the foundation of the modern banking system and is essential to the operation of a state’s financial sector. A stable financial sector encourages the growth of jobs, a stable economy, and enlarges the state’s tax base [*ibid.*: 161].

The state derives its legitimacy from successfully meeting these functions, and interventions in failed states should be organized to restore a state’s ability to meet these requirements.

Haims *et al.* [2008:9-21] describe a failed state cycle. Figure 6 illustrates the idea of concentrating efforts on the critical challenges which overlap between insecurity, economic collapse, and unfit government. They posit that failed states exhibit three conditions that result from this cycle: exposure to danger, lack of opportunity, and unresponsive government; and that stabilization operations should be targeted to combat these conditions.

The United States Institute of Peace (USIP) has developed a strategic “Framework for Success” for stabilization and reconstruction in unstable states and post-conflict states. Their framework, intended primarily for use in planning and organizing operations, identifies five key “desired end states” for stabilization and

reconstruction operations [USIP 2007]. USIP's five key desired end states and their constituent key objectives are reproduced in Table 1.

Carlos Pascual, Vice President and Director for Foreign Policy Studies at the Brookings Institution, in his testimony before Congress, identified four imperatives for any stabilization operation.

1. Stabilization: The first task of an intervening force is to impose peace and ensure law and order. They must also, during this time, provide for basic humanitarian needs.
2. Unraveling the past: The intervention must address the original causes of the conflict.
3. Building infrastructures, laws, and institutions of democracy and market economy: The intervening force must lay the foundations for future peace and stability in the region — to facilitate the transition from imposed peace to a sustainable peace.
4. Nurturing civil society: The intervening force should facilitate the growth of media, civic organizations, business groups, etc. [Pascual 2008].

2.2.2 State Department Stabilization and Reconstruction Policy

The State Department's Coordinator for Reconstruction and Stabilization (S/CRS) has compiled a list of essential post-conflict tasks [DoS 2005]. The list is organized into five sectors: Security; Governance and Participation; Humanitarian Assistance and Social Well-Being; Economic Stabilization and Infrastructure; and Justice and Reconciliation. Figure 7 shows an excerpt from the Economic Stabilization and Infrastructure sector of the task list. Each of these categories includes tasks broken out into subcategories and into three time phases of operations: Initial Response, Transformation, and Fostering Sustainability. S/CRS provides by far the most detailed openly available plan for stabilization and reconstruction operations.

Table 1 USIP Framework for Success

Safe and Secure Environment	Rule of Law	Stable Democracy	Sustainable Economy	Social Well-being
Prevent renewal of fighting (e.g., enforce ceasefire; secure weapons/stockpiles; disarm, demobilize, and reintegrate former fighters)	Establish coherent, legitimate, and just legal frameworks (e.g., constitution, criminal, and civil frameworks)	Build effective and legitimate executive institutions—national, regional, and local levels (e.g., ministries, civil service)	Reconstruct infrastructure (e.g., electricity, communications, transportation)	Ensure population is fed
Protect civilians (e.g., counter organized crime, de-mine)	Build effective and independent courts	Develop legitimate systems of political representation—national, regional, and local levels (e.g., legislatures)	Promote sound fiscal/economic policy	Ensure population has water
Ensure freedom of movement (e.g., for civilians, relief workers, peace monitors)	Build effective police, customs, immigration, and border control forces	Promote free and responsible media	Build effective financial and economic institutions (e.g., banks)	Ensure population has shelter
Protect key historical, cultural, and religious sites, as well as important buildings, property, and infrastructure	Build effective legal profession/bar	Promote the creation of political parties	Create viable workforce	Meet basic sanitation needs
Protect witnesses and evidence of atrocities	Protect human rights	Promote robust civil society and civic participation (including minorities and marginalized groups)	Promote business development and sustainable employment; increase access to capital	Meet basic health needs
Protect international borders/airspace/ports of entry	Ensure equal access to justice and equal application of the law		Protect, manage, and equitably distribute natural resources/revenues	Build effective education system
Build effective security forces, under civilian control	Promote public awareness and legal empowerment		Limit/contain corruption and illicit economy	Enable displaced persons and refugees to return or relocate
				Address legacy of past abuses (e.g., truth commissions)
				Promote peaceful coexistence (e.g., inter-ethnic, interfaith)

[USIP 2007:2]

Reconstruction and Stabilization Essential Tasks

SECURITY

	INITIAL RESPONSE	TRANSFORMATION	FOSTERING SUSTAINABILITY
	<i>Goal: Establish a safe and secure environment</i>	<i>Goal: Develop legitimate and stable security institutions</i>	<i>Goal: Consolidate indigenous capacity</i>
Disposition of Armed and Other Security Forces, Intelligence Services and Belligerents			
Cessation of Hostilities	<ul style="list-style-type: none"> Enforce ceasefires Supervise disengagement of belligerent forces Identify and neutralize potential spoilers Negotiate terms for exchange of prisoners of war Engage indigenous forces capable of promoting immediate stability 	<ul style="list-style-type: none"> Establish and control buffers, including demilitarized zones Monitor exchange of POWs 	<ul style="list-style-type: none"> Transfer monitor requirements to indigenous security institutions
Enforcement of Peace Agreements and/or Other Arrangements	<ul style="list-style-type: none"> Provide security for negotiations among indigenous belligerents Develop confidence-building measures between indigenous belligerents Conduct counterinsurgency operations 	<ul style="list-style-type: none"> Investigate alleged breaches of agreements Support and enforce political, military, and economic terms arrangements Support confidence-building measures amongst belligerents 	<ul style="list-style-type: none"> Transfer enforcement requirements to indigenous authorities Support and sustain confidence-building measures
Disposition and Constitution of National Armed Services	<ul style="list-style-type: none"> Implement plan for disposition of indigenous armed forces and other national security institutions Identify future roles, missions and structure Vet senior officers and other individuals for past abuses Coordinate and integrate with DDR plans 	<ul style="list-style-type: none"> Train and equip indigenous military forces Establish transparent entry, promotion, and retirement systems Establish programs to support civilian oversight of military 	<ul style="list-style-type: none"> Provide conventional military assistance programs Establish military-to-military programs with the host country's forces Sustain international support
Disarmament	<ul style="list-style-type: none"> Negotiate arrangements with belligerents Establish and enforce weapons control regimes, including collection and destruction 	<ul style="list-style-type: none"> Disarm belligerents Reduce availability of unauthorized weapons Collaborate with neighboring countries on weapons flows, including 	<ul style="list-style-type: none"> (I) Secure, store, and dispose of weapons Develop indigenous arms control capacity

I-1

[DoS 2005:I-1]

Figure 7 Excerpt from S/CRS's Essential Task List

2.2.3 MPICE

Measuring Progress in Conflict Environments (MPICE) is an interagency effort by the United States Institute of Peace, the United States Army Corps of Engineers, USAID, and the United States Army Peacekeeping and Stability Operations Institute [USIP 2008]. The MPICE framework focuses on measuring progress in five Level I *Sectors*:

1. Political Moderation and Stable Democracy
2. Safe and Secure Environment
3. Rule of Law
4. Economic Sustainability
5. Social Well Being.

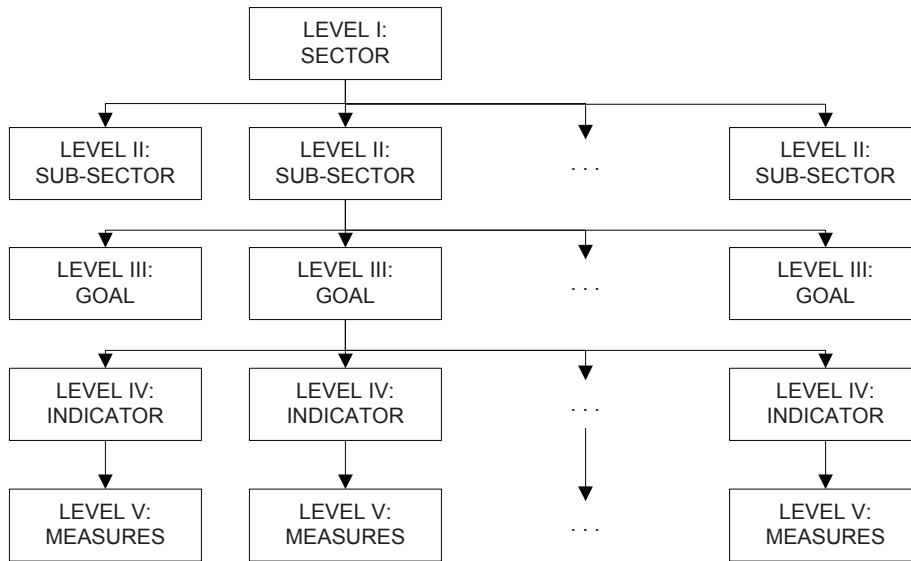


Figure 8 MPICE Heirarchy

Each of these sectors comprises two Level II *Sub-Sectors*: Conflict Drivers and Institutional Performance. These Sub-Sectors are further divided into Level III *Goal*, Level IV *Indicator*, and Level V *Measure*. Figure 8 illustrates the MPICE heirarchy.

MPICE uses four methods to collect each measure [USIP 2008:5]:

1. Content Analysis (CA): Data collected by CA is gleaned from open-source media publications to gauge popular opinions about an issue. The data are freely available, but the process is labor-intensive.
2. Expert Knowledge (EO): EO data are collected from a panel of “independent, knowledgeable, and experienced experts” in a particular field of study.
3. Statistical Analysis(SA): SA data come from analysis of statistics about security, economic development, and so forth in a particular region.
4. Survey and Polling Data (S/PD): S/PD come from opinion surveys on a variety of issues pertaining to the conflict.

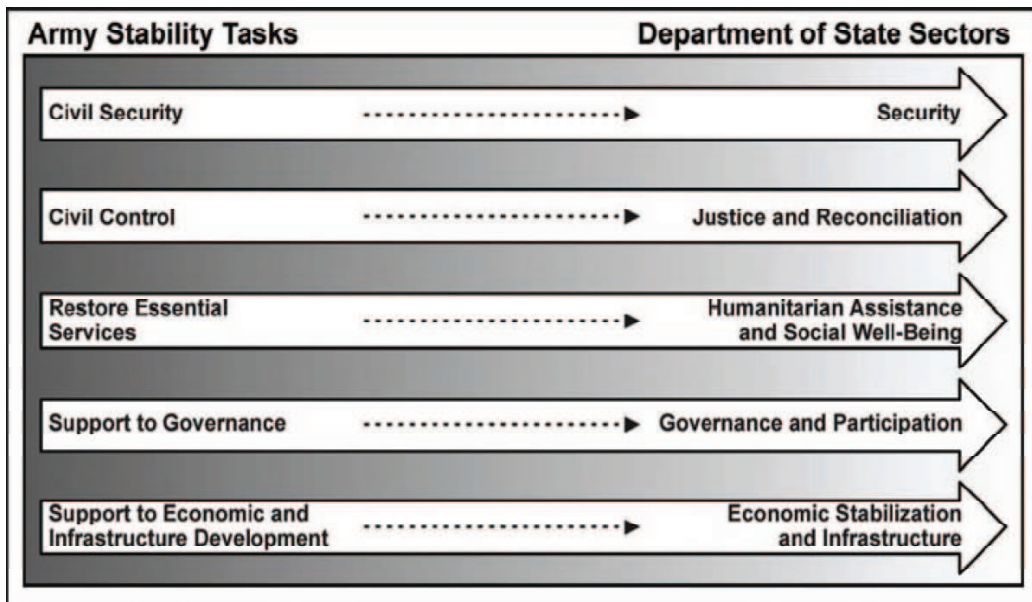
2.2.4 *Joint Doctrine*

In the newly revised Joint Publication 1 [JP 1], SSTR operations are now featured as a key element of US Joint Doctrine. JP 1 lists stability operations as a key type of operation for the Department of Defense equal in importance to defensive and offensive operations [JP 1 2008:ii]. JP 1 goes on to say that it is not sufficient to bring about a quick conclusion to hostilities, but that the operations must bring about “conditions favorable to the [Host Nation] and the United States and its multinational partners” [*ibid.*:I-17], and that:

Establishing these conditions often requires conducting stability operations in support of broader stability, security, transition, and reconstruction (SSTR) efforts. Stability operations are a core US military mission that helps to establish order that advances US interests and values. The immediate goal often is to provide the local populace with security, restore essential services, and meet humanitarian needs. The long-term goal is to help develop indigenous capacity for securing essential services, a viable market economy, rule of law, democratic institutions, and a robust civil society. . . . Further, some military operations normally will continue after the conclusion of combat operations. An extended US presence will be required to conduct stability operations to enable legitimate civil authority and attain the national strategic end state. It must be considered throughout planning and execution that stability operations may be required to attain the national strategic end state. These stability operations historically have required an extended presence by US military forces to assist by conducting stability operations. This contingency should be considered during the initial [course of action] development and recommendation for execution. [JP 1 2008:I-17–I-18]

2.2.5 *US Army Doctrine*

Like joint doctrine, stabilization operations now feature prominently in Army doctrine. In Field Manual (FM) 3-0, the Army now places Stability on par with Offense, Defense, and Civil Support Operations [FM 3-0 2008:3-7]. FM 3-0 outlines five Stability Tasks: Civil Security, Civil Control, Restore Essential Services, Support



[FM 3-0:3-15]

Figure 9 Army Tasks support S/CRS Sectors

to Governance, and Support to Economic and Infrastructure Development which the Army explicitly links to the S/CRS’s Essential Task List sectors (Figure 9).

US Army Field Manual 3-07 Stability Operations and Support Operations governs US Army contributions to SSTR Operations. It addresses the tasks associated with conducting (planning, preparing, executing, and assessing) stability operations and support operations at the strategic level. *Peace Operations: Multi-Service Tactics, Techniques, and Procedures for Conducting Peace Operations* — co-listed as FM 3-07.31, MCWP 3-33.8, and AFTTP (I) 3-2.40 — provides a Tactics, Techniques, and Procedures (TTP) manual for conducting “peace operations (PO) at the brigade level of warfighting”. It gives guidance for training for and planning joint peace operations at the tactical level.

2.2.6 Non-Governmental Organization (NGO) Guidance

The Sphere Project provides information on minimum requirements for humanitarian interventions [Sphere Project 2004]. Although the standards are designed for

humanitarian relief following natural disasters, the requirements for humanitarian relief following a military conflict will be comparable. The Sphere Project organizes humanitarian relief into four sectors:

- Water, Sanitation, and Hygiene Promotion,
- Food Security, Nutrition, and Food Aid,
- Shelter, Settlement, and Non-food Items, and
- Health Services.

They establish minimum standards for relief efforts common to all four sectors and specific standards for each sector.

2.2.7 Summary of SSTR Operations Literature

The support in the literature for facilitating economic development and for the importance of reconstructing critical infrastructure is unanimous. Covey *et al.* include access to a legitimate economy to provide for basic necessities in their ten keys to successful interventions [Covey *et al.* 2005]. Ghani and Lockhart include the provision of infrastructure services and the formation of a market as two of their essential services performed by a legitimate state government [Ghani and Lockhart 2008]. Haims *et al.* cite a lack of economic opportunity as key cause of state failure [Haims *et al.* 2008]. Pascual includes building infrastructure and a market economy in his four imperatives for any stabilization operation [Pascual 2008]. A sustainable economy is one of USIP's five desired end states, and reconstructing infrastructure is the first task listed for that goal [USIP 2007]. Economic Stabilization and Infrastructure is one of S/CRS's five sectors in their Post-Conflict Reconstruction Essential Tasks and consequently are featured in both JP 1 and FM 3-0 which derive their SSTRO tasks from the S/CRS's essential task list.

2.3 *Economic Welfare*

Given the consensus in SSTRO literature on the importance of facilitating economic development, some method of measuring the economic status of a community is needed. To that end, this section presents a brief survey of the field of Welfare Economics.

Whereas *positive economics* is the hard, quantitative facet of economics, *welfare economics* is the facet of economics where the fuzzy issues of *good* and *bad* or *should* and *should not* resurface. Welfare economics collates the pertinent theoretical aspects of positive economics in support of the economic welfare of the community [Rothenberg 1961:3].

Bergson (with significant input from Samuelson) first introduced the concept of the Welfare Function in 1938. Bergson sought to isolate the value-based or ethical assumptions of welfare economics from its analytical techniques [Rothenberg 1961:8]. He began by proposing an unspecified relationship between a community's welfare and variables like the amounts of certain factors of production, the amounts of various commodities consumed, and so forth [Bergson 1938:311]. The analyst could isolate ethical assumptions in this function and trace out their implications.

As an example, if x_i and y_i are two kinds of consumer goods used by a given individual i , a_i and b_i are the amounts of two kinds of labor performed by individual i for each of the goods, C and D are the amounts of other non-labor factors used for each of the two goods, and r, s, t, \dots are other unspecified factors affecting the welfare of the community, then for individuals $i = 1, 2, \dots, n$, Bergson's welfare function takes the form [Bergson 1938:312]:

$$W = W(x_1, y_1, a_1^x, b_1^x, a_1^y, b_1^y, \dots, \\ x_n, y_n, a_n^x, b_n^x, a_n^y, b_n^y, C^x, D^x, C^y, D^y, r, s, t, \dots)$$

Bergson assumes that while changes in the non-economic factors, r, s, t, \dots , can affect a community's welfare, the community's welfare is insensitive to those variables under normal circumstances. Thus, the Welfare Function, W , can be reformulated as an *Economic Welfare Function* [*ibid.*]:

$$E = E(x_1, y_1, a_1^x, b_1^x, a_1^y, b_1^y, \dots, \\ x_n, y_n, a_n^x, b_n^x, a_n^y, b_n^y, C^x, D^x, C^y, D^y | r, s, t, \dots)$$

Bergson is not saying that an individual's or community's welfare does not depend on any non-economic factors — such an assumption would be blatantly incorrect — but only that within the range of normal economic analysis, these non-economic factors do not significantly affect the value of E .

Although Bergson's original formulation depended on factors of production and consumption, the economic welfare function is not limited to those variables, and economists have developed welfare functions based on other factors. Van Praag uses a Welfare Function of Income (WFI) to measure welfare in Belgium [1971]. Wansbeek and Kapteyn use WFIs to demonstrate welfare functions' ability to link theory and practice [1983]. Their functions take the general form:

$$\mu = \beta_0 + \beta_1 \ln(fs) + \beta_2 \ln(y) + v$$

where β_0 , β_1 , and β_2 are regression constants, fs is a measure of family size, y is after-tax income, and v is a random noise variable with an expected value of 0 [*ibid.*:253].

Henderson — also endeavoring to bridge the gap between theory and empiricism — uses a welfare function based on per capita personal income Y , per capita revenue R , population P , per capita public expenditure G , and per capita private

expenditure X :

$$W = (\alpha_0 + \alpha_1 Y + \alpha_2 R + \alpha_3 P) \ln G + X$$

where α_0 , α_1 , α_2 , and α_3 are regression constants [1968:156].

Some have argued that Arrow's impossibility theory rendered welfare economics irrelevant [Kemp and Ng 1976, Parks 1976] — this may account for the relative sparsity of recent welfare economics literature — however, Fleurbaey and Mongin refute this argument and conclude that “[b]y taking the shape of an explicitly defined BSF [Bergson-Samuelson Function], these theories may be turned into proper tools” for economic evaluations [2005].

The conclusion is that there is a generally accepted positive relationship between income and economic welfare (*i.e.*, $W \propto y$). This is important to Chapter III's formulation of a mathematical model for reconstruction operation planning.

2.4 Program Management and Project Scheduling

Within the scope of project management, organizing tasks is a primary responsibility of the project manager. The organization of tasks into logical groupings for progress and budgetary tracking can be assisted by the use of a Work Breakdown Structure; and the sequencing of tasks in an order that satisfies precedence and resource limitations can be completed by using sound project scheduling techniques.

2.4.1 Work Breakdown Structures

The Work Breakdown Structure (WBS) grew — alongside PERT — out of project management efforts in the Department of Defense in the late 1950s. Although definitions of a WBS vary, Pritchard defines it as “a decomposition of the work to be performed that is arranged in a hierarchy and constructed to allow for clear logical grouping of the tasks to be performed or the deliverables to be provided” [1998:2].

- 1. Organizational Move
 - 1.1. Network Move
 - 1.1.1. Server Move
 - 1.1.2. Backup Systems Move
 - 1.1.3. Workstation Move
 - 1.1.3.1. Word Processing Workstation Move
 - 1.1.3.2. Data Entry Workstation Move
 - 1.1.3.2.1. Sun Workstation Transfer
 - 1.1.3.2.2. M/S Workstation Transfer
 - 1.1.3.2.3. Mac Workstation Transfer
 - 1.1.3.3. Customer Service Workstation Move
 - 1.2. Equipment Move
 - 1.3. Personnel Move

[Pritchard 1998:7-8]

Figure 10 Example Work Breakdown Structure

Whether the WBS is task- or deliverable-oriented, it will have the same overall form. The highest level (the project level) is identified by a project number assigned by the initiating organization. Typically, within an organization, this project will be unique to facilitate tracking the project within the organizations portfolio of projects. For this illustration, the project number is 1, and the top level of the WBS is 1.x.

The next level (1.1, 1.2, ..., 1.n) lists the groups or components within the project, and the third level lists subgroups or subcomponents within those groups or components: 1.1.1, 1.1.2, ..., 1.1.m, 1.2.1, 1.2.2, ..., 1.n.m. This structure continues until there is a numerical hierarchy which covers the entirety of the project. Thus, 1.i.j.k is the *k*th *work package* within the *j*th subcomponent of the *i*th component of project 1. An example from Pritchard is shown in Figure 10.

The work package is the lowest level of project control [Demeulemeester and Herroelen 2002:15] and represents the work required to complete a specific job or process. It may consist of one or more activities. Responsibility for a work package is assigned to a single organization or individual. It is important that the work packages not be too large. However, Pritchard relates a recognized rule of thumb

among project managers: “a WBS is too detailed when it tells team members, ‘Move Left Foot, Move Right Foot’ ” [1998:2].

2.4.2 *WBS and Scheduling*

Deckro, Hebert, and Verdini develop a Work Package Scheduling Model which uses work packages and their constituent activities to perform budget and schedule trade-offs between work packages in light of an overall project due date and budget [1992]. The problem is formulated as a linear program.

Wiley exploits the block diagonal structure induced by the work package structure to develop a solution using Danzig-Wolfe decomposition. He uses this model to illustrate balancing resources between multiple defense acquisition projects [1996].

2.4.3 *The Resource Constrained Project Scheduling Problem (RCPSP)*

Artigues gives this informal definition of the Resource-Constrained Project Scheduling Problem (RCPSP):

[The RCPSP] considers resources of limited availability and activities of known durations and resource requests, linked by precedence relations. The problem consists of finding a schedule of minimal duration by assigning a start time to each activity such that the precedence relations and the resource availabilities are respected [2008:21].

Formally, the RCPSP is a combinatorial optimization problem with a discrete solution space, X , a set of feasible solutions, $\chi \in X$, and an objective function, $f : \chi \rightarrow \mathbb{R}$. The combinatorial optimization problem seeks a solution, $x \in \chi$, such that $f(x) = \min \{f(y) : y \in \chi\}$. Specifically, the RCPSP is defined by:

1. A set of activities, $V = \{1, 2, \dots, n\}$: Conventionally (though not universally) activities 1 and n are dummy activities representing the start and finish of the project.

2. A set of activity durations, $d = \{d_1, \dots, d_n\}$. By definition, $d_1 = d_n = 0$. In the deterministic RCPSP, the duration of each activity is known with certainty before the start of the project.
3. A set of zero-lag, finish-start precedence relations, $E = \{e_1, e_2, \dots, e_m\}$ where $e_k = (i, j)$ means that activity j cannot begin until activity i is finished.
4. A set of K renewable resources, $R = \{R_1, R_2, \dots, R_K\}$.
5. A set of availabilities, $A = \{a_1, a_2, \dots, a_k\}$, where a_i denotes the availability of resource R_i .
6. A set of \bar{K} nonrenewable resources with their capacities, $a_{\bar{i}}$ for $i = \bar{1}, \bar{2}, \dots, \bar{K}$.
7. A set of demands such that r_{ij} represents the demand of activity i for resource j . By definition, $r_{1j} = r_{nj} = 0$ for $j = 1, 2, \dots, K$ and $j = \bar{1}, \bar{2}, \dots, \bar{K}$.

A solution to the RCPSP is represented by a schedule, $S = \{s_1, s_2, \dots, s_n\}$, where s_i is the start time of activity i . $f_i = s_i + d_i$ is the finish time activity a_i . Because $d_n = 0$, $s_n = f_n$ is the finish time (or *makespan*) for the entire project. Conventionally, the start time of the initial dummy activity, 1, is defined as 0.

2.4.4 Generalized Precedence Extension of the RCPSP

A key assumption in classical RCPSP and PERT/CPM scheduling is that all precedence relations are of the zero-lag, finish-start type. However, in practice, this is often not a valid assumption. When expanding precedence relations beyond the restrictive assumption of finish-start constraints, most of the literature follows Elmaghraby and Kamurowski [1992] using the term Generalized Precedence Relations (GPR).

GPR distinguishes between four types of precedence relations: start-to-start (or “start-start”, SS), start-to-finish (“start-finish,” SF), finish-to-start (“finish-start,” FS), and finish-to-finish (“finish-finish,” FF). Further, GPRs may represent a minimum or maximum lag between the finish and/or start times of a pair of activ-

ities. Minimal time lags (denoted by $SS_{ij}^{\min}(x)$, $SF_{ij}^{\min}(x)$, $FS_{ij}^{\min}(x)$, $FF_{ij}^{\min}(x)$) state that activity j 's start (or finish) time must lag the start (or finish) time of activity i by at least x time units. Similarly, maximal time lags ($SS_{ij}^{\max}(x)$, $SF_{ij}^{\max}(x)$, $FS_{ij}^{\max}(x)$, $FF_{ij}^{\max}(x)$) state that activity j 's start (or finish) time may lag activity i 's start (or finish) by no more than x time units [Demeulemeester and Herroelen 2002:40].

2.4.5 Minimal Time Lags

Finish-start relations are the most intuitive of the GPRs. $FS_{ij}^{\min}(0)$ is the common zero-lag delay of PERT/CPM. Activity i can begin immediately following the completion of activity j . If $x \neq 0$, then the specified amount of time after the finish of activity i must elapse before event j may start: construction of the frame of a house must wait until the concrete of the foundation has had enough time to cure [*ibid.*].

Start-start relations indicate a delay between the start of activity i and the start of activity j . For example, painting the interior of a house must lag behind the installation of drywall, but the drywall work need not be completed in the entire house before painting can begin [*ibid.*:41].

Coordinating the completion of activities is common in projects, and so finish-finish relations are quite common in project scheduling. $FF_{ij}^{\min}(x)$ relations model a required lag in the completion of activity j to process the output of activity i [*ibid.*].

Start-finish relations are the least common of the four types and do not occur frequently in practice [*ibid.*:41–42].

It is also possible to combine the relations listed above. Demeulemeester and Herroelen use the example of framing a house and installing the electrical system. The electricians cannot start until the framers have completed some work

Table 2 Maximal-Minimal Equivalencies

GPRs w/ Maximal Relations	GPRs w/ Minimal Relations
$FS_{ij}^{\min}(x)$	$SF_{ij}^{\min}(-x)$
$SS_{ij}^{\min}(x)$	$SS_{ij}^{\min}(-x)$
$SF_{ij}^{\min}(x)$	$FS_{ij}^{\min}(-x)$
$FF_{ij}^{\min}(x)$	$FF_{ij}^{\min}(-x)$

[Demeulemeester and Herroelen 2002:44]

(an $SS_{ij}^{\min}(x)$ relationship), but they also need time to continue working after the framers are done (an $FF_{ij}^{\min}(x)$ relationship) [*ibid.*:42].

2.4.6 Maximal Time Lag

A maximal start-start relation ($SS_{ij}^{\max}(x)$) can model the requirement that an activity start no later than a prescribed period after the start of another. A maximal start-finish relation ($SF_{ij}^{\max}(x)$) can represent a deadline for completing a particular activity. If activity i is the dummy project-start activity, then $SF_{ij}^{\max}(x)$ can require that activity j finish no more than x time units after the start of the project [*ibid.*42–43].

2.4.7 Minimal-Maximal Equivalencies

Any maximal time lag can be converted into a minimal time lag in the opposite direction. For example, a maximal finish-start relation, $FS_{ij}^{\max}(x)$, between activities i and j implies the constraint $f_i + x \geq s_j$. Multiplying the constrain by -1 leads to the constraint $-f_i - x \leq -s_j$ or $s_j - x \leq f_i$ which is simply a minimal start-finish relation from j to i , $SF_{ji}^{\min}(-x)$. Table 2 lists the maximal relations and their minimal equivalents [*ibid.*:44].

2.4.8 Multi-Mode Extension to the RCPSP

The Multi-Mode Resource Constrained Project Scheduling Problem (MM-RCPSP) differs from the traditional RCPSP in that activities may be processed

in multiple ways [Bellenguez-Morineau and Emmanuel Néron 2008]. The different processing methods - modes - have different costs and different durations: a package may be shipped by FedEx at a cost of \$30 with a duration of 2 days, or it may be shipped by USPS at a cost of \$5 with a duration of 5 days.

The notation for the MM-RCPSP is the same as the basic RCPSP with the following additions:

1. A number of modes, M_i , to execute each activity $i \in A$.
2. The processing time of activity a_i , d_i , becomes d_{im} , the processing time for activity a_i using mode m .
3. The resource requirements of activity a_i , r_{ij} , becomes r_{imj} , the amount of resource R_j required by activity i in mode m .

2.4.9 Solving the RCPSP

The basic RCPSP seeks to minimize the makespan of the project while respecting the precedence and resource constraints. The RCPSP is strongly \mathcal{NP} -hard [Blazewicz, Lenstra, and Rinnooy Kan 1983]. Several authors have presented branch-and-bound solution procedures. Most of which branch off of partial schedules; that is, the nodes of the search tree correspond to partial schedules, and the branching step adds at least one activity to the partial schedule [Néron 2008]. Most studies use heuristics and meta-heuristics to solve medium and large instances [Bellenguez-Morineau and Néron 2008].

The basic RCPSP is \mathcal{NP} -hard [Blazewicz *et al.* 1983], and the RCPSP can be seen as a special case of the MM-RCPSP where $M_i = 1 \forall i \in A$; therefore, the MM-RCPSP is \mathcal{NP} -hard. As with the basic RCPSP, branch-and-bound techniques are used to produce optimal solutions; however, branch and bound may be prohibitively expensive to compute for medium and large sized problems. Many studies use heuristics and meta-heuristics to solve medium and large instances [Bellenguez-Morineau

and Néron 2008]. Sprecher and Drexel present a branch-and-bound technique which uses search tree reduction techniques to increase the performance of the algorithm [1998]. Hartmann and Drexel examine the solution procedures suggested by four authors [1998]. Their computational experiment determined that the procedure by Sprecher and Drexel [1998] is the most efficient.

2.5 Goal Programming

The concept of goal programming is generally attributed to Charnes, Cooper, and Ferguson's 1955 paper on executive compensation schemes; however, the term *goal programming* did not appear until 1961 [Schniederjans 1995]. Goal programming is an extension of linear programming to handle multiple, often-conflicting objective measures. Each measure is assigned a goal, and the deviations from this goal are minimized.

Preemptive goal programming (sometimes called *lexicographic GP modeling*) assumes that the decision maker can rank the objectives from most to least important. PGP makes no attempt to assign weights to the different measures; instead it assigns each a preemptive ranking. If P_i is the objective function ranking of goal i , preemptive goal programming assumes that

$$P_1 \ggg P_2 \ggg \dots \ggg P_n.$$

The decision maker attempts to satisfy each goal in order; that is, P_1 is satisfied, then P_2 is satisfied as much as it can be without decreasing P_1 's optimality, and so on [Charnes and Cooper 1977]. If δ_i^+ is the positive deviation (*i.e.*, deviation over the goal) and δ_i^- is the negative deviation from the goal (deviation under the goal),

the general formulation of a PGP problem is

$$\min \sum_i P_i (\delta_i^+ + \delta_i^-)$$

subject to

$$\sum_{j=1}^n a_{ij}x_j - \delta_i^+ + \delta_i^- = b_i, \text{ for } i = 1, \dots, m$$

$$\delta_i^+, \delta_i^-, x_j \geq 0, \text{ for } i = 1, \dots, m; \text{ for } j = 1, \dots, n.$$

2.6 Summary

This chapter presented a review of the current literature that is pertinent to planning SSTR operations. The literature on SSTR operations is unanimous in its support for the importance of rebuilding infrastructure and for facilitating the revitalization of a legitimate economy in a post-conflict region. The literature on project scheduling contains a number of useful models which can be combined with goal programming to schedule reconstruction activities. Chapter III develops an extension of the Multimodal Resource Constrained Project Scheduling Problem with Generalized Precedence Relations for use in SSTR operations.

III. Formulation

3.1 Introduction

This chapter develops a mathematical programming model for scheduling reconstruction activities to maximize the potential positive economic impact of projects during the initial response phase of SSTR operations. Section 3.2 gives a mathematical programming formulation of the MultiModal RCPSP with Generalized Precedence Relations (MM-RCPSP-GPR). The next section, 3.3, develops how that formulation can be applied to SSTRO and expands the formulation to include goal programming and economic benefit. Section 3.4 gives the final statement of the full goal programming MM-RCPSP-GPR model.

3.2 Formulating the MM-RCPSP-GPR as an Integer Linear Program

In the Integer Program (IP) of the multimodal RCPSP with GPRs, two assumptions are made to simplify the formulation. First, it is assumed that all maximal time lags are transformed into minimal time lags as described in Table 2 in the previous chapter, and second, it is assumed that the GPRs are not dependant on the mode selected for each activity. Next, the edge sets, E_{SS} , E_{SF} , E_{FS} , and E_{FF} are defined as the resulting sets of minimal SS -, SF -, FS -, and FF -precedence relations. The values for the time lags are SS_{ij} for $(i, j) \in E_{SS}$, SF_{ij} for $(i, j) \in E_{SF}$, FS_{ij} for $(i, j) \in E_{FS}$, and FF_{ij} for $(i, j) \in E_{FF}$. Finally, define T as an upper bound on the project duration, es_i as the earliest start time for activity i , and ls_i as the latest start time for activity i .

Table 3 MM-RCPSP-GPR Notation

Symbol	Description	Symbol	Description
N	number of activities	SF_{ij}	time lag for $(i, j) \in E_{SF}$
M_i	number of modes of execution for activity i	E_{FS}	FS -precedence relations
d_{im}	duration of activity i in mode j	FS_{ij}	time lag for $(i, j) \in E_{FS}$
es_i	earliest start time for activity i	E_{FF}	FF -precedence relations
ls_i	latest start time for activity j	FF_{ij}	time lag for $(i, j) \in E_{FF}$
T	overall project due date	a_k	availability each time unit of renewable resource k
E_{SS}	SS -precedence relations	K	number of renewable resources
SS_{ij}	time lag for $(i, j) \in E_{SS}$	$a_{\bar{k}}$	availability of renewable resource \bar{k}
E_{SF}	SF -precedence relations	\bar{K}	number of nonrenewable resources

3.2.1 MM-RCPSP-GPR Notation

A complete list of the parameters used in the formulation of the IP is given in Table 3. All information is assumed to be given in the problem instance except for es_i and ls_i which are computed as described in Subsection 3.2.2.

The traditional objective for the MM-RCPSP-GPR is to assign a start time and mode to each activity without violating resource availability or GPR constraints while minimizing the overall project duration. Defining the decision variables

$$x_{imt} = \begin{cases} 1 & \text{if activity } i \text{ is started at time } t \text{ in mode } m \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

the MM-RCPSp-GPR can be formulated as follows [De Reyck and Herroelen 1999:541]:

$$\min \sum_{t=es_N}^{ls_N} tx_{N1t} \quad (2)$$

subject to

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} x_{imt} = 1, i = 1, 2, \dots, N \quad (3)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + SS_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (tx_{jmt}), (i, j) \in E_{SS} \quad (4)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + SF_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (t + d_{jm}) x_{jmt}, (i, j) \in E_{SF} \quad (5)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + d_{im} + FS_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (tx_{jmt}), (i, j) \in E_{FS} \quad (6)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + d_{im} + FF_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (t + d_{jm}) x_{jmt}, (i, j) \in E_{FF} \quad (7)$$

$$\sum_{i=1}^n \sum_{m=1}^{M_i} \left(r_{imk} \times \sum_{s=\max\{t-d_{im}, es_i\}}^{\min\{t-1, ls_i\}} x_{ims} \right) \leq a_k, k = 1, 2, \dots, K, t = 1, 2, \dots, T \quad (8)$$

$$\sum_{i=1}^n \sum_{m=1}^{M_i} \left(r_{im\bar{k}} \times \sum_{t=es_i}^{ls_i} x_{imt} \right) \leq a_{\bar{k}}, \bar{k} = 1, 2, \dots, \bar{K}, \quad (9)$$

$$x_{imt} \in \{0, 1\}, i = 1, 2, \dots, N, \quad (10)$$

$$m = 1, 2, \dots, M_i, t = 1, 2, \dots, T$$

The objective function's (2) value will be the time of the final dummy activity's completion, and thus it minimizes the project duration. The first set of constraints (3) ensures that each activity is assigned exactly one mode and one start time. The next sets of constraints — (4), (5), (6), and (7) — prevent the solution from violating any of the GPRs. Equation (8) prevents the demands for any renewable resource from exceeding that resource's availability during any time unit, and equa-

tion (9) prevents the total demand for any nonrenewable resource from exceeding that resource’s availability during the entire project. Finally, equation (10) forces the decision variables to take binary values.

Constraint (3) constitutes a series of type 1 special ordered sets — ordered sets of variables in which at most one member of each set can be strictly positive, all others must be zero. This structure can be exploited by the solution process [Beale and Forrest 1976].

3.2.2 Computing the Early and Late Start Times

Building from the work of Pritsker, Watters, and Wolfe [1969], to reduce the number of decision variables required, each activity’s start time may be bounded by its early and late start times. To compute the early and late start times, one must find the *time-feasible* schedule which minimizes and maximizes each activity start time subject to these constraints:

$$s_i \geq 0 \quad \forall i \in V \tag{11}$$

$$s_i + SS_{ij} \leq s_j \quad \forall (i, j) \in E_{SS} \tag{12}$$

$$s_i + SF_{ij} \leq f_j \quad \forall (i, j) \in E_{SF} \tag{13}$$

$$f_i + FS_{ij} \leq s_j \quad \forall (i, j) \in E_{FS} \tag{14}$$

$$f_i + FF_{ij} \leq f_j \quad \forall (i, j) \in E_{FF} \tag{15}$$

$$\exists m \leq M_i : d_{im} = f_i - s_i \quad \forall i \in V \tag{16}$$

where s_i and f_i are the start and finish times of activity i respectively. When each activity has only one mode, the durations are fixed. In this case, all GPRs can be reduced to minimal *SS* relations and the early and late start times can be computed through well-known graph algorithms [De Reyck and Herroelen 1999:542]. However, when activities have more than one mode, the calculation is more complicated. If the MM-RCPSp has only zero-lag finish-start relations, then the early and late start

times can be figured by assigning each activity its shortest-duration mode and using CPM methods. If the project has GPRs, then calculating the *exact* early and late starts for each activity can be as difficult as solving the MM-RCPSP [*ibid.*].

One way to compute the exact early and late start times for the MM-RCPSP-GPR in the most complicated case (*i.e.*, an instance with more than one mode and GPRs) would be to modify the above constraints into a linear program. Equation (16) can be rewritten as:

$$\sum_{m=1}^{M_i} y_{im} = 1 \quad \forall i \in V \quad (17)$$

$$s_i + \sum_{m=1}^{M_i} d_{im} y_{im} - f_i = 0 \quad \forall i \in V \quad (18)$$

$$y_{im} \in \{0, 1\} \quad (19)$$

where

$$y_{im} = \begin{cases} 1 & \text{if activity } i \text{ is executed in mode } m \\ 0 & \text{otherwise} \end{cases} \quad (20)$$

The new equation (17) ensures that each activity is started in only one mode, and the equation (18) ensures that each activity's finish and start times agree with one of its modes. Equation (19) forces y_{im} to assume binary values as defined in (20). Thus the complete program for computing early (late) start times is:

$$\min(\max) \sum_{i=1}^n s_i$$

subject to

$$(12), (13), (14), (15)$$

$$\sum_{m=1}^{M_i} y_{im} = 1 \quad \forall i \in V$$

$$s_i + \sum_{m=1}^{M_i} d_{im} y_{im} - f_i = 0 \quad \forall i \in V$$

$$s_i \geq 0 \quad \forall i \in V$$

$$y_{im} \in \{0, 1\}$$

However, this approach simply replaces one \mathcal{NP} -hard problem with another. Heilmann presents two polynomially-bounded algorithms for generating schedules which bound the early start times for the MM-RCPSp-GPR [2003]; however, he does not suggest an approach for computing late-start schedules. Fredley proposes the use of the Generalized Critical Path Method (GCPM) to compute early and late start times for activities with generalized precedence relationships. The GCPM algorithm is as follows [Fredley 2001:3-10-3-11]:

1. Set es_i for each i equal to the release date of the project.
2. For each activity, i , in numerical order, set es_i to the greatest of
 - (a) es_i ,
 - (b) $es_j + d_j$ of each of i 's standard predecessors j ,
 - (c) es_j plus the minimum time lag between j and i for each j that is a generalized predecessor of i .
3. If any es_i changed in step 2, repeat step 2.

4. Set ls_i to $T - d_i$.
5. For each activity, i , in reverse numerical order, set ls_i to the least of
 - (a) ls_i ,
 - (b) $ls_j - d_i$ for each of i 's standard successors j ,
 - (c) ls_j minus the minimum time lag between i and j for each j that is a generalized successor of i .
6. If any ls_i changed in step 5, repeat step 5.

Using the GCPM, the early and late start times for each activity are determined by [Fredley 2001:3-11 – 3-12]:

1. Relax all the resource constraints in the problem. Consider only the precedence relations, and
2. Using the shortest-duration mode of each activity, determine the activities' early and late start times.

3.3 Expanding the MM-RCPSP-GPR for SSTRO

The expanded model's objective is to meet the planned completion date for the restoration of essential power and water services while effectively creating jobs during the immediate post-conflict reconstruction by selecting activity execution modes that make use of the local workforce throughout the affected region(s). The goal is not to create "make-work" projects, but to prioritize the employment of local workers when choosing between alternative modes of execution for legitimate reconstruction activities. It is assumed that the modes considered by the model are legitimate, effective options based on local conditions.

The model uses goal programming to satisfice attainment levels for the assigned due dates for the restoration of essential services, desired employment levels in each region of the reconstruction area, and desired average income level of the activities.

The model can represent programs ranging from the simple, illustrative example presented in Chapter IV to a realistically scaled SSTR operation comprising hundreds or thousands of activities spanning an entire country.

3.3.1 Model Assumptions

The model makes certain important assumptions. Among them are:

1. A level of security has already been established.
2. As it is intended for the immediate post-conflict reconstruction phase, the planning horizon for this model is approximately one year, as conditions warrant.
3. Activities may not be *crashed*; that is, an activity's duration may not be decreased by increasing its resource level. Variability in an activity's duration is modeled through multiple execution modes with different durations.
4. Precedence relations are constant over an activity's different modes.

3.3.2 Extraction of Activities from the S/CRS WBS

S/CRS provides the most comprehensive publicly available list of activities in its Initial Response tasks [DoS 2005]. This list of tasks can be reorganized into a Work Breakdown Structure (see Appendix A) and activities can be extracted from it as described by Wiley *et al.* [1998]. Working from the WBS excerpt shown in Figure 11, the decision maker may conclude that repairing a power generation plant and a power substation are important reconstruction tasks. These tasks could be added to the WBS as “4.14.3.1.1 Repair Power Plant” and “4.14.3.1.2 Repair Power Substation.”

For example, tasks falling under work package 3.6.2.1, covering the provision of sanitary water, and work package 4.14.3.1, covering the provision of electricity, may be of primary importance in the initial phase of reconstruction. Activities falling

3. HUMANITARIAN ASSISTANCE AND SOCIAL WELL-BEING

3.6. Public Health

3.6.2 Sanitation and Waste Water Management

3.6.2.1 Ensure proper sanitation, purification, and distribution of drinking water

4. ECONOMIC STABILIZATION AND INFRASTRUCTURE

4.12. Transportation

4.14. Energy

4.14.3 Energy Infrastructure

4.14.3.1 Assess condition of existing natural resources conversion and distribution facilities, and power generation and distribution facilities

Figure 11 Excerpt from S/CRS WBS

under 4.12, Transportation, may be important enablers or prerequisites for work in 3.6.2.1 and 4.14.3.1.

For each activity drawn from the WBS, its modes of execution include performing the task organically (assigning it to an available construction batallion, USACE, *etc.*) or contracting the task to bids supplied by local or international businesses. No mathematical model can replace a qualified contracting officer, however, and this model assumes that the bids (modes) have been vetted by a qualified contracting officer and meet any applicable requirements for minimum livable wages and time- and resource-feasibility.

3.3.3 Goals and Constraints

Recalling that the general form of a goal program is

$$\min \sum_i P_i (\delta_i^+ + \delta_i^-)$$

subject to

$$\sum_{j=1}^n a_{ij}x_j - \delta_i^+ + \delta_i^- = b_i, \text{ for } i = 1, \dots, m$$

$$\delta_i^+, \delta_i^-, x_j \geq 0, \text{ for } i = 1, \dots, m; \text{ for } j = 1, \dots, n,$$

the decision maker must analyze each of the goals. If under-achievement is acceptable, only δ_i^+ need be included in the objective function; if over-achievement is acceptable, only δ_i^- need be considered. Further, if goals m and n are of equal priority, their deviations must be considered in the same objective function and they must be weighted relative to one another

$$\min \sum_i P_i (w_m \delta_m^+ + w_m \delta_m^- + w_n \delta_n^+ + w_n \delta_n^-)$$

[Lee and Clayton 1972].

For this demonstration, goals are introduced to encourage timely restoration of essential power and water services, equitable distribution of employment opportunities, and a sustainable wage level in the area of operations. Other policies and goals could be modeled, as required. The resource availabilities and precedence relations are left as firm constraints; however, if there is flexibility in resource availability, these constraints could also be converted into goals.

3.3.4 *The Resource Constraints*

The decision maker may add additional resources for consideration, but the basic demonstration model includes the following resources:

Organic Elements: The reconstruction authority will initially have only a limited number of construction battalions, Red Horse squadrons, PRT's, *etc.* to assign

to reconstruction tasks. These units can be assigned to reconstruction projects as execution modes which do not require any local labor.

Laborers: While the labor pool may be large, the number of local workers is finite. In the Initial Response phase, it may be sufficient to assume that activities draw workers from a large, homogenous body. In later phases, however, such an assumption would not be realistic: while a surgeon can drive a cab if it is the only paying work available, a cab driver would not be an ideal surgeon. If the data are available, the labor pool can be divided by skills.

Supervisors: Often, the most limiting resource is the number of qualified supervisors available. While it may not be feasible to institute managerial training programs in the initial response phase, as the reconstruction effort progresses, increasing thought should be given to developing future supervisors in accordance with S/CRS Initial Response activity 3.7 Education [DoS 2005].

Funds: Cost may be a limiting factor. If funds are allocated by region or by sector, a decomposition technique like that proposed by Wiley *et al.* may be applicable to balance funds [1998].

3.3.5 *The Precedence Constraints*

Precedence constraints are used to ensure that activities do not commence before their prerequisites have achieved the required level of completion. The advantages of using generalized precedence rather than the simpler zero-lag finish-start relations common in PERT/CPM include the abilities to synchronize task completions (Finish-Finish relations), to establish deadlines for one activity relative to another (Start-Finish relations), and to establish lead times (Start-Start relations).

For example, if the repairs to a port facility must progress to a given level before it can be used to process supplies needed for other reconstruction activities, a start-start precedence relation with a lag equal to the required lead time could

be used to represent this requirement. If a water well requires external power to run, then a finish-finish relation can synchronize the completion of the well with the completion of repairs to the local power grid.

On the other hand, if the decision maker does not have sufficient data to include generalized precedence relations, the model is capable of processing zero-lag finish-start scheduling without modification.

3.3.6 The First Goal: Timely Restoration of Services

In reconstruction operations, one of the most important tasks is restoring essential services, power and water, in a timely fashion [Haims *et al.* 2008:23–25]. To ensure this, the model includes two dummy activities with zero duration and zero resource demands: activities w and p . Each water or power repair activity has a minimal zero-lag finish-start precedence relation to its appropriate dummy activity, and the dummy activities have target completion times T_{water} and T_{power} . Defining δ_w^+ and δ_w^- as the lateness and earliness for the target water service restoration date, and δ_p^+ and δ_p^- as the lateness and earliness for the target power service restoration date, these goals are formulated

$$\sum_{t=es_w}^{ls_w} tx_{w1t} - \delta_w^+ + \delta_w^- = T_{\text{water}} \quad (21)$$

$$\sum_{t=es_p}^{ls_p} tx_{p1t} - \delta_p^+ + \delta_p^- = T_{\text{power}}, \quad (22)$$

and the corresponding priority 1 (P_1) PGP objective function is

$$P_1 (\delta_w^+ + \delta_p^+). \quad (23)$$

The two due dates are weighted equally, and the objective function is penalized only for exceeding the due dates as given by δ_w^+ and δ_p^+ in (23).

3.3.7 The Second Goal: Job Creation

In post-conflict reconstruction, economic impact can be one of the most important aspects of SSTR operations. S/CRS recommends designing “initiatives to provide immediate employment” and creating “opportunities for young males” via public works jobs in its initial response tasks [DoS 2005]. However, the traditional MM-RCPSP-GPR does not include information on the employment difference between the modes of execution for a given activity.

If the area of SSTR operations is large enough to warrant it, planning will need to include the issue of balancing employment opportunities between regions within the area of operations — *e.g.*, balancing jobs between governorates within Iraq. To accomplish this, a measure of economic benefit is indexed to reflect the benefit in a particular region for each activity’s execution modes. If the area of operations has regions $g = 1, 2, \dots, G$, then

e_{img} = the employment benefit of activity i executed in mode m to region g

and

W_g = The working-age population of region g for $g = 1, 2, \dots, G$.

The employment benefit of activity i will be measured by the number of jobs created by each contract bid or proposed execution mode for i . Thus, if the second contract proposal for activity 1 creates 15 jobs in region 3, $e_{1,2,3} = 15$. There may be disagreement on whether direct measurement of employment is the most effective measure of economic benefit; however, given the expected dearth of information in the immediately post-conflict period, it may be the only measure available. If more effective measures are available, the definition of e_{img} can be adjusted to incorporate such measures.

To encourage an equitable distribution of employment opportunities, the model includes a second goal where δ_{eg}^+ and δ_{eg}^- are deviations above and below the target employment level, $J_g \in [0, 1]$ in each region g :

$$\frac{1}{W_g} \sum_{i=2}^{N-1} \left(\sum_{m=1}^{M_i} \left(e_{img} \sum_{t=es_i}^{ls_i} x_{imt} \right) \right) - \delta_{eg}^+ + \delta_{eg}^- = J_g \quad (24)$$

with the priority 2 (P_2) objective function

$$P_2 \left(\sum_{g=1}^G \delta_{eg}^- + \delta_{eg}^+ \right). \quad (25)$$

The goal (24) is penalized for deviating under or over this employment goal (25) — this will help prevent an imbalance in job creation between regions. J_g is currently defined as the jobs created per capita by the reconstruction for each region. If the employment goal exceeds the current unemployment rate in region g , the goal may be unreachable, or the reconstruction may pull workers away from other employment.

Assigning each region an individual goal allows the decision maker to encourage a particular level of employment in each region. The decision maker could set J_g higher in rural areas to mitigate population migration to urban areas. Haims *et al.* assert that, in SSTR operations, public investment should be concentrated in areas with high unemployment of excombatants [2008:10] — the decision maker could set J_g higher in these regions. The goal programming approach allows this flexibility in modeling.

3.3.8 The Third Goal: Sustainable Wages

The literature on social welfare is consistent in acknowledging the positive relation between *income* and social welfare (see Section 2.3). In the short-term, simply creating employment is a sufficient stop-gap solution; however, as the reconstruction progresses, increasing emphasis should be given to developing the workforce. To that

end, the model includes a third goal to allow the assignment of a target average-income level for the activities. μ_{img} is the income rating of activity i in mode m to region g , $\mu_{\text{goal},g}$ is the target income level for region g , $\delta_{\mu g}^-$ and $\delta_{\mu g}^+$ are the deviations below and above the target income level, and the goal has the form

$$\frac{1}{N-2} \sum_{i=2}^{N-1} \sum_{m=1}^{M_i} \mu_{img} \sum_{t=es_i}^{ls_i} x_{imt} + \delta_{\mu g}^- - \delta_{\mu g}^+ = \mu_{\text{goal},g} \text{ for } g = 1, \dots, G. \quad (26)$$

The wages are averaged by $N - 2$ to account for the two dummy activities, which can never add to the income rating. The priority 3 (P_3) PGP objective function is

$$P_3 \left(\sum_{g=1}^G \delta_{\mu g}^- \right). \quad (27)$$

Suitable measures for μ_{img} may be wages or wages plus the multiplier effect. If the data are available, the $\mu_{\text{goal},g}$ could be set at certain multiple of that region's pre-conflict median income or to a suitably large number ("big M ") if the decision maker wants to maximize the income level. The selection of measures for this goal will depend on the information available to the decision maker.

If the situation warrants it, this goal can be refined to allow (for example) per-quarter income goals, $\mu_{\text{goal},g,q}$ for $q = 1, 2, 3, 4$. In the first quarter, employment could be paramount and income could be nearly irrelevant, but the income goal could gradually increase each quarter. The PGP approach allows this flexibility; however, it would come at the modeling price of increasing the dimensionality of the problem.

3.4 *Final Statement of the Goal-Programming Model*

The the final PGP model for the MM-RCPSG-GPR including timing and employment goals is as follows:

$$\text{minimize } P_1 (\delta_w^+ + \delta_p^+) \quad (28)$$

$$P_2 \left(\sum_{g=1}^G \delta_{eg}^- + \delta_{eg}^+ \right) \quad (29)$$

$$P_3 \left(\sum_{g=1}^G \delta_{\mu g}^- \right) \quad (30)$$

subject to

(Timely Restoration of Services Goal)

$$\sum_{t=es_w}^{ls_w} tx_{w1t} - \delta_w^+ + \delta_w^- = T_{\text{water}} \quad (31)$$

$$\sum_{t=es_p}^{ls_p} tx_{p1t} - \delta_p^+ + \delta_p^- = T_{\text{power}} \quad (32)$$

(Job Creation Goal)

$$\frac{1}{W_g} \sum_{i=2}^{N-1} \left(\sum_{m=1}^{M_i} \left(e_{img} \sum_{t=es_i}^{ls_i} x_{imt} \right) \right) - \delta_{eg}^+ + \delta_{eg}^- = J_g, \text{ for } g = 1, \dots, G \quad (33)$$

(Sustainable Wages Goal)

$$\frac{1}{N-2} \sum_{i=2}^{N-1} \sum_{m=1}^{M_i} \mu_{img} \sum_{t=es_i}^{ls_i} x_{imt} + \delta_{\mu g}^- - \delta_{\mu g}^+ = \mu_{\text{goal},g} \text{ for } g = 1, \dots, G \quad (34)$$

(One Mode for Each Activity)

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} x_{imt} = 1, i = 1, 2, \dots, n \quad (35)$$

(Precedence Relations)

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + SS_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (tx_{jmt}), (i, j) \in E_{SS} \quad (36)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + SF_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (t + d_{jm}) x_{jmt}, (i, j) \in E_{SF} \quad (37)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + d_{im} + FS_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (tx_{jmt}), (i, j) \in E_{FS} \quad (38)$$

$$\sum_{m=1}^{M_i} \sum_{t=es_i}^{ls_i} (t + d_{im} + FF_{ij}) x_{imt} \leq \sum_{m=1}^{M_j} \sum_{t=es_j}^{ls_j} (t + d_{jm}) x_{jmt}, (i, j) \in E_{FF} \quad (39)$$

(Resource Constraints)

$$\sum_{i=1}^N \sum_{m=1}^{M_i} r_{imk} \sum_{s=\max\{t-d_{im}, es_i\}}^{\min\{t-1, ls_i\}} x_{ims} \leq a_k, k = 1, 2, \dots, K, t = 1, 2, \dots, T \quad (40)$$

$$\sum_{i=1}^N \sum_{m=1}^{M_i} r_{im\bar{k}} \sum_{t=es_i}^{ls_i} x_{imt} \leq a_{\bar{k}}, \bar{k} = 1, 2, \dots, \bar{K} \quad (41)$$

(Variable Domains)

$$x_{imt} \in \{0, 1\}, i = 1, 2, \dots, N, \quad (42)$$

$$m = 1, 2, \dots, M_i, t = 1, 2, \dots, T$$

$$\delta_{eg}^+, \delta_{eg}^- \geq 0 \text{ for } g = 1, \dots, G \quad (43)$$

$$\delta_w^+, \delta_w^-, \delta_p^+, \delta_p^-, \delta_\mu^-, \delta_\mu^+ \geq 0 \quad (44)$$

Equations (28), (29), and (30) are the objective functions for the priority 1, 2, and 3 preemptive goals. (28) minimizes the lateness of the restoration of essential services. (29) minimizes the shortfall of employment levels. (30) minimizes the shortfall in the average income ratings.

Equations (31), (32), (33), and (34) are the program goals. (31) and (32) force the completion dates for the water and power restorations towards the target dates. (33) pushes the employment levels towards the goal for each region. (34) pushes the average income ratings towards the goal for each region.

Equation (35) forces the solution to select one and only one mode and start time for each activity. Equations (36), (37), (38), and (39) enforce the general precedence relations, and equations (40) and (41) enforce the renewable and nonrenewable resource availabilities.

The final equations (42), (43), and (44) define the variable domains. The x_{imt} variables are binary, and the deviation variables are non-negative.

While the proposed model, for early periods of the reconstruction effort, has focused on establishing services, employment, and income, the goal programming approach allows for the inclusion of various goals. With some analysis, the reconstruction authority will be able to model goals that are appropriate for a given situation.

3.5 Summary

In this chapter, a mathematical formulation of the MM-RCPSG-GPR was developed. The model includes goals to ensure timely restoration of essential services, to preferentially select execution modes that make equitable use of the local workforce, and to prefer activity execution modes that meet sustainable income goals. In the next chapter, this model will be applied to a notional reconstruction project to illustrate its application.

IV. Illustrative Analysis

4.1 Introduction

This chapter presents an analysis of a notional SSTR operation to illustrate the approach developed in this research. First, Section 4.2 provides an overview of the scenario. Section 4.3 applies the MM-RCPSP-GPR model to the scenario at an aggregate level: it develops a list of project activities with resource and precedence constraints; defines the levels of resources available; and describes the modes of execution available for each activity. Finally, Section 4.4 presents the schedule generated by the model.

4.2 Notional Scenario

This section presents an SSTRO scenario in a notional region. The numbers of activities, modes, regions, and resources have been set artificially low to facilitate visual presentation of the scenario. A brief background of the scenario is given, including an outline of the conflict and the cessation of hostilities.

4.2.1 Conflict Background

The region in question is a province of a notional former French colony, Acadie, (Figure 12) which gained its independence in the 1960s. Since then, like so many former colonies, it has experienced significant civil strife. In the province of Acadie de l'Ouest, this conflict recently escalated to the point that it gained international attention. The UN agreed to send a peacekeeping force to the area, and security was restored. However, significant damage had been done to the Acadie de l'Ouest's infrastructure and institutions.



Figure 12 Map of Acadie

Table 4 Demographics of Acadie de l'Ouest

Population	10,000
Age structure	0-14 years: 25%; 15-64 years: 50%; \geq 65 years: 25%
Median age	30 years
Ethnic groups	Former Colonists 45%, Indigenous 45%, Creole 5%, Other 5%
Religions	Roman Catholic 45%, Indigenous religions 50%, other 5%
Languages	French, Local

4.3 Model Application

4.3.1 Reconstruction Goals

The UN Reconstruction Authority (UNRA) has decided not to break the area of operations into smaller subregions, thus $G = 1$ in the model. With inputs from several other government agencies and NGO's, the UNRA has decided on the following goals for the reconstruction effort:

1. Restoration of independent water and power services within six months — $T_{\text{water}} = T_{\text{power}} = 24$ weeks.
2. Local job creation rate of 30 new jobs per 100 workers — $J = 0.30$.
3. Maximize income level — $\mu_{\text{goal},1}$ is set to a “big M ” that is larger than it can possibly attain in order to force the average income rating as high as possible: $\mu_{\text{goal},1} = 30$.

4.3.2 Resources Available

As summarized in Table 5, the reconstruction authority has estimated the local working population to be about 2,000 (the population of healthy males between the ages of 15 and 64, in deference to local cultural mores), about 50 individuals with significant managerial training still reside in the province, and the UNRA includes two construction units.

Table 5 Resources

Resource	Availability
Workers	2,000
Supervisors	50
Organic Construction Units	2

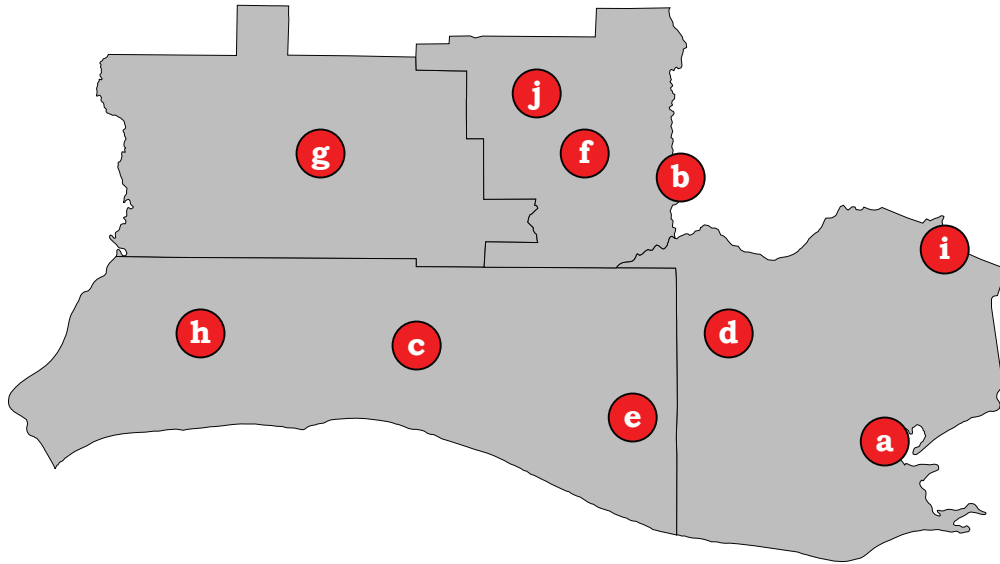


Figure 13 Acadie de l'Ouest and Reconstruction Projects (a – j)

4.3.3 Reconstruction Activities

For this example, the model components are aggregated, high-level reconstruction projects; however, the model elements can be resolved down to the decision maker's desired level of detail.

Figure 13 shows the conflict region. The reconstruction projects selected by the UNRA are labeled *a* through *j* and are shown in their respective locations. The reconstruction projects and dummy projects are outlined and assigned reference numbers in Table 6.

Table 6 Reconstruction Projects

Proj.	#	Description	Proj.	#	Description
start	1	Dummy Start	g	8	Local Well
a	2	Port	h	9	NG Well
b	3	Highway	i	10	Power Substation
c	4	Irrigation Sys.	j	11	Local Water Sys.
d	5	Power Plant	water	12	Dummy Power
e	6	Water Plant	power	13	Dummy Water
f	7	Local Well	finish	14	Dummy Finish

Projects 1 and 14 are the artificial start and finish events. Projects 13 and 14 are the artificial water and power events; the realization of these events represent the restoration of water and power services used in Goal 1. Projects 2, 3, 4, and 9 are general infrastructure repairs.

- *Project 2*: The province's main port facility is in need of repair; it is important to begin this job quickly because the port is needed to move supplies to the other reconstruction activities.
- *Project 3*: The province is linked to its neighbor to the east by one main highway. This highway must be repaired to facilitate moving supplies to accomplish repairs in the north.
- *Project 4*: To restart farming in the southwest, the irrigation system must be repaired.
- *Project 9*: To begin restoring trade, repairs must be made to the province's primary natural gas wellhead.

Projects 5 and 10 are power service infrastructure repairs.

- *Project 5*: The province has one major power plant which requires repairs before it can be brought back on line.
- *Project 10*: The power substation linking the province with its neighbor to the east has suffered from severe neglect and requires maintenance before it can be reactivated.

Projects 6, 7, 8, and 11 are water service infrastructure repairs.

- *Project 6*: The province's main water treatment plant has been damaged.
- *Projects 7 & 8*: The rural areas of the province are dependent on local wells for potable water; these wells require repairs.
- *Project 11*: The local water/sewage distribution system in one area requires repairs to restore sanitation services.

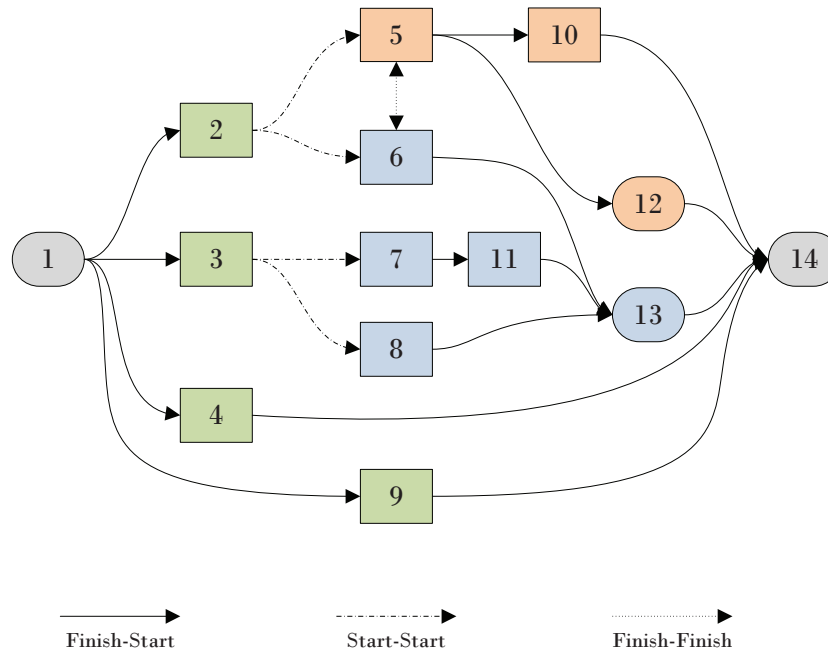


Figure 14 Project Precedence Relations

4.3.4 Precedence Relations

Before any projects can be scheduled, the decision maker must define the precedence relations.

In this scenario, the two projects which must begin before any others are repairs to the province’s port facilities (project #2) and to the main highway connecting the province to the rest of the region (#3). Port and highway repairs must progress sufficiently to allow their use for delivering supplies to effect the other repairs; however, they need not be completed before other repairs can begin. Start-start precedence relations between the port repairs and the repairs to the power plant (#5) and the water treatment plant (#6) will restrict the plants’ repairs from beginning until the port repairs have made progress: $s_3 + 10 \leq s_5$ and $s_3 + 10 \leq s_6$, the start times of #5 and #6 (s_5, s_6) must lag the start time of #2 (s_2) by 10 weeks. Similarly, start-start precedence relations will ensure sufficient delay between the highway repair (#3) and the local well repairs (#7, #8).

The port repairs can progress in advance of the power and water because supplies and power can be provided by ships in dock; likewise, the highway repair can proceed in advance of water and power because supplies can be brought in from the neighboring province.

In addition, the timing of repairs to the power plant (#5) and water treatment plant (#6) must be coordinated. The power plant cannot be brought fully online without sufficient water for cooling, and the treatment plant needs electricity to operate. To ensure the plants' repairs end concurrently, their finish times are related through a zero-lag finish-finish precedence. Once the power plant is repaired, the power substation tying the province's electrical grid to its neighboring province must be repaired (#10).

Because much of the province is rural, the population is highly dependent on local wells for potable water. Repairs to these local water wells (#7, #8) and to the water distribution system in the northeast (#11) must be completed to restore water services.

Finally, there are two independent infrastructure projects: repairing the irrigation system (#4) and a natural gas wellhead in the southwest (#9).

Figure 14 illustrates these precedence relations. General infrastructure projects are shown in green; water projects are blue; and power projects are orange. Dummy projects to track the restoration of water and power and the end of reconstruction are shown with rounded corners.

4.3.5 Modes, Durations, and Demands

The UNRA has gathered bids from local and international companies for each project. For each project, each feasible bid is assigned as an execution mode. There is no inherent limit on the number of modes for each activity.

Each bid for each project includes expected demands for the various resources of interest to the decision maker: laborers, supervisors, funds, and so forth.

To keep the instance size manageable for this illustrative example, each project has three execution modes: Completion by an Organic Construction Unit assigned to the peacekeeping force (Mode 1), by an International Company (Mode 2), or by a Local Company (Mode 3). Each mode has an expected duration in weeks as described in Table 7, and resource demands as in Table 8.

Table 7 Project Mode Durations

i	Description	d_{i1}	d_{i2}	d_{i3}	i	Description	d_{i1}	d_{i2}	d_{i3}
1	Dummy Start	0	100	100	8	Local Well	1	2	3
2	Port	30	40	50	9	NG Well	40	45	50
3	Highway	7	7	14	10	Power Substation	3	6	12
4	Irrigation Sys.	3	6	9	11	Local Water Sys.	5	7	9
5	Power Plant	12	24	40	12	Dummy Power	0	100	100
6	Water Plant	13	20	25	13	Dummy Water	0	100	100
7	Local Well	1	2	3	14	Dummy Finish	0	100	100

Table 8 Project Mode Resource Demands

i	Description	r_{i11}	r_{i21}	r_{i31}	r_{i12}	r_{i22}	r_{i32}	r_{i13}	r_{i23}	r_{i33}
1	Dummy Start	0	0	0	0	0	0	0	0	0
2	Port	1	0	0	0	2	10	0	10	275
3	Highway	1	0	0	0	2	10	0	5	137
4	Irrigation Sys.	1	0	0	0	2	10	0	1	25
5	Power Plant	1	0	0	0	2	10	0	8	180
6	Water Plant	1	0	0	0	2	10	0	5	112
7	Local Well	1	0	0	0	2	10	0	1	27
8	Local Well	1	0	0	0	2	10	0	1	25
9	NG Well	1	0	0	0	2	10	0	8	200
10	Power Substation	1	0	0	0	2	10	0	2	60
11	Local Water Sys.	1	0	0	0	2	10	0	2	50
12	Dummy Power	0	0	0	0	0	0	0	0	0
13	Dummy Water	0	0	0	0	0	0	0	0	0
14	Dummy Finish	0	0	0	0	0	0	0	0	0

4.3.6 Early and Late Starts

The early and late start times in weeks for each project were computed as described in Subsection 3.2.2; the times are listed in Table 9. The code formulation

Table 9 Project Early and Late Start Times

i	Description	es_i	ls_i	i	Description	es_i	ls_i
1	Start Event	1	13	8	Local Well	11	51
2	Port	1	23	9	NG Well	1	13
3	Highway	1	37	10	Power Substation	24	50
4	Irrigation Sys.	1	50	11	Local Water Sys.	12	47
5	Power Plant	12	38	12	Power Event	24	52
6	Water Plant	11	37	13	Water Event	24	52
7	Local Well	11	47	14	Finish Event	41	52

used to generate these start times is included in Appendix B.

4.4 Model Solution

The model was solved using the data from the previous section and the goal programming formulation presented in Section 3.4. The dimensionality of the instance necessitates the use of a matrix generator. LINGO was used to generate and solve this instance; however, there are other equally capable IP generators such as GAMS. The solution was generated on a Hewlett-Packard desktop computer with these specifications: AMD Athlon™ 64 X2 Dual at 2.19 GHz with 960 MB of RAM using LINGO 11.0.0.20. The formulation includes 1203 variables and 197 constraints.

While the model is large even for this small example, an advantage of goal programming is that the optimum objective function value is known; as soon as a given goal's deviation is reduced to 0, the branch-and-bound algorithm can terminate. This often *significantly* reduces the solution time of goal programs versus other integer programs. The IP for the first goal was generated and solved in 17 seconds, the second in 25 seconds, and the third in 33 seconds.

The specific LINGO formulation and the data files used are collected in Appendix B.

4.4.1 The First Goal: Timely Restoration of Essential Services

The first goal attempts to restore essential water and power services on or before a target date subject to the precedence relations by minimizing only the deviations *over* this target date.

Solving the integer program for the first goal, restoration of water and power services in 24 weeks, produces the solution in Table 10.

Table 10 P_1 Timely Restoration of Services

i	Description	m_i	s_i	d_{im}	f_i	i	Description	m_i	s_i	d_{im}	f_i
1	Start Event	1	1	0	1	8	Local Well	3	20	3	23
2	Port	2	1	40	41	9	NG Well	2	7	45	52
3	Highway	3	1	14	15	10	Power Substation	2	46	6	52
4	Irrigation Sys.	2	2	6	8	11	Local Water Sys.	2	17	7	24
5	Power Plant	1	12	12	24	12	Power Event	1	24	0	24
6	Water Plant	1	11	13	24	13	Water Event	1	24	0	24
7	Local Well	1	11	1	12	14	Finish Event	1	52	0	52

The deviation variables have the values:

$$\begin{aligned} \delta_{\text{power}}^- &= 0, & \delta_{\text{power}}^+ &= 0 \\ \delta_{\text{water}}^- &= 0, & \delta_{\text{water}}^+ &= 0 \\ \delta_e^- &= 0.1425, & \delta_e^+ &= 0 \\ \delta_\mu^- &= 19.35, & \delta_\mu^+ &= 0 \end{aligned}$$

The power and water goals are both attained. The per-capita jobs created are about half the goal: there is room for improvement.

In this first goal schedule, water and power are restored at exactly 24 weeks ($s_{12} = s_{13} = 24$), and repairs to the port and highway start immediately ($s_2 = s_3 =$

1). Only two jobs are assigned mode 3, execution by a local company. This accounts for the low job creation rate indicated by $\delta_e^- = 0.1425$.

4.4.2 The Second Goal: Job Creation

The second goal attempts to select modes of execution for each project that result in a target level of job creation by minimizing both the deviations *over* and *under* this target level while maintaining the satisfaction of the first goal. The objective is not to create “make-work” projects or maintain a certain level of employment, but rather, given a set of projects to accomplish, to give preferential selection to modes of execution that result in higher (or lower, as determined by J_g) use of the local workforce.

Each project mode’s expected number of local jobs created was developed and the results are shown in Table 11.

Table 11 Project Mode Job Creation

i	Description	e_{i1}	e_{i2}	e_{i3}	i	Description	e_{i1}	e_{i2}	e_{i3}
1	Start Event	0	0	0	8	Local Well	0	3	35
2	Port	0	12	285	9	NG Well	0	10	210
3	Highway	0	7	147	10	Power Substation	0	4	70
4	Irrigation Sys.	0	3	35	11	Local Water Sys.	0	4	60
5	Power Plant	0	10	190	12	Power Event	0	0	0
6	Water Plant	0	7	122	13	Water Event	0	0	0
7	Local Well	0	3	37	14	Finish Event	0	0	0

Solving the integer program for the second goal, equitable creation of employment opportunity, produces the solution in Table 12. The job creation goal changed the modes of execution for projects 2, 3, 7, 9, and 11. Projects 2, 9, and 11 changed from international companies to local companies; project 3 changed from a local company to an organic construction unit; and project 7 changed from an organic construction unit to an international project.

Table 12 P_2 Equitable Employment Opportunities

i	Description	m_i	s_i	d_{im}	f_i	i	Description	m_i	s_i	d_{im}	f_i
1	Start	1	1	0	1	8	Local Well	3	21	3	24
2	Port	3	1	50	51	9	NG Well	3	1	50	51
3	Highway	1	1	7	8	10	Power Substation	2	44	6	50
4	Irrigation Sys.	2	1	6	7	11	Local Water Sys.	3	14	9	23
5	Power Plant	1	12	12	24	12	Power Event	1	24	0	24
6	Water Plant	1	11	13	24	13	Water Event	1	24	0	24
7	Local Well	2	12	2	14	14	Finish Event	1	52	0	52

The new values of the deviation variables are:

$$\delta_{\text{power}}^- = 0, \quad \delta_{\text{power}}^+ = 0$$

$$\delta_{\text{water}}^- = 0, \quad \delta_{\text{water}}^+ = 0$$

$$\delta_e^- = 0, \quad \delta_e^+ = 0$$

$$\delta_{\mu}^- = 29.29, \quad \delta_{\mu}^+ = 0$$

Power and water service restoration times are still maintained. The per capita job creation, however, is now exactly equal to the goal of 0.30. The income attainment is significantly worse than its previous attainment level; the next goal attempts to improve the income attainment level.

4.4.3 The Third Goal: Sustainable Income Levels

The third goal attempts to set the average income rating to a desired level, $\mu_{\text{goal},g}$, while maintaining the satisfaction of the first two goals. In this instance, $\mu_{\text{goal},1}$ is set to a value larger than it can possibly attain, $\mu_{\text{goal},1} = 30$. This will force the average income rating as high as possible to minimize the deviation *under* the target. The income rating of each project mode was calculated based on the ratio of the mode's median wage to the pre-conflict median wage in the area of operation. These ratings are shown in Table 13.

Table 13 Project Mode Income Ratings

i	Description	μ_{i1}	μ_{i2}	μ_{i3}	i	Description	μ_{i1}	μ_{i2}	μ_{i3}
1	Start Event	0	0	0	8	Local Well	0	0.8	0.8
2	Port	0	1	1	9	NG Well	0	1	1.1
3	Highway	0	0.9	1	10	Power Substation	0	0.8	0.8
4	Irrigation Sys.	0	1	1.2	11	Local Water Sys.	0	0.9	1.2
5	Power Plant	0	1.2	1.1	12	Power Event	0	0	0
6	Water Plant	0	0.8	0.8	13	Water Event	0	0	0
7	Local Well	0	1.2	0.9	14	Finish Event	0	0	0

Solving the integer program for the third goal, sustainable income levels, produces the solution in Table 14. The sustainable income goal changed the modes of execution for projects 4, 7, 8, 9, and 10. Projects 4, 7, and 10 have changed from international companies to local companies; projects 8 and 9 have changed from local companies to international companies.

Table 14 P_3 Sustainable Income Levels

i	Description	m_i	s_i	d_{im}	f_i	i	Description	m_i	s_i	d_{im}	f_i
1	Start Event	1	1	0	1	8	Local Well	2	11	2	13
2	Port	3	1	50	51	9	NG Well	2	1	45	46
3	Highway	1	1	7	8	10	Power Substation	3	24	12	36
4	Irrigation Sys.	3	1	9	10	11	Local Water Sys.	3	15	9	24
5	Power Plant	1	12	12	24	12	Power Event	1	24	0	24
6	Water Plant	1	11	13	24	13	Water Event	1	24	0	24
7	Local Well	3	11	3	14	14	Finish Event	1	52	0	52

The new values of the deviation variables are:

$$\delta_{\text{power}}^- = 0, \quad \delta_{\text{power}}^+ = 0$$

$$\delta_{\text{water}}^- = 0, \quad \delta_{\text{water}}^+ = 0$$

$$\delta_e^- = 0, \quad \delta_e^+ = 0$$

$$\delta_{\mu}^- = 19.31, \quad \delta_{\mu}^+ = 0$$

In this schedule, the solution to the complete model, the attainment levels for the first two goals are maintained, but the attainment for the income goal has been improved to 10.69.

In the final schedule, water and power are still restored at 24 weeks ($s_{12} = s_{13} = 24$). The port and highway repairs start immediately ($s_2 = s_3 = 1$). Repairs to the irrigation system and natural gas well start immediately as well ($s_4 = s_9 = 1$). The water and power plant repairs start at week 12 and 11 ($s_5 = 12, s_6 = 11$). The local well repairs start at week 11 ($s_7 = s_8 = 11$) after the highway repair has progressed for 10 weeks. The power substation project starts at week 24 ($s_{10} = 24$) after the power plant is completed. And repairs to the local water system start at week 15 ($s_{11} = 15$) after the first well (#7) is completed.

4.4.4 Sensitivity Analysis

Schniederjans lists several types of changes that can be made for sensitivity analysis in goal programming [1995]. Of those listed, two are applicable to the current problem: (1) reordering preemptive constraints and (2) changes to right-hand-side values.

With respect to changes of type (1), exchanging the order of goals 1 and 2, the timing and employment goals, does not change the solution because goals 1 and 2 can be satisfied ($\delta_e^- = \delta_e^+ = \delta_{\text{power}}^+ = \delta_{\text{water}}^+ = 0$) simultaneously. Moving income to the highest priority (regardless of the order of the other two) allows $\delta_{\mu}^- = 18.97$ and has the effect of pushing the power and water completion dates to 11 weeks late and the job creation rate to 0.0045 below the goal of 0.30. Given humanitarian considerations, this is not likely to be desirable unless other temporary means of restoring services are available. Alternative priorities can be investigated, however, as required.

Examining changes of type (2), shortening the deadline for power and water restoration can make the first goal unattainable. Increasing the job creation goal

does not effect the timing of the goal, but it makes the job creation goal unsatisfiable ($\delta_e^- \neq 0$) and worsens the deviation of the income goal slightly. Changing the income goal does not significantly change the solution because, being the third priority goal, there is not that much room for increase or decrease.

Hence, for this problem instance, the order of the priorities can be changed to suit the decision maker without dramatically changing the solution produced. However, the problem instance is sensitive to changes in the targets for the three goals.

4.4.5 Example Application of a Project Monitoring Tool

One of the key advantages to using project scheduling is that it allows the decision maker to take advantage of established project monitoring tools. One way of measuring the progress of an entire project is the aggregate measure *earned value* [Meredith and Mantel 2000:428].

Earned value management developed from the DoD's PERT/Cost and Cost/Schedule Control System Criteria (C/SCSC). Earned value management compares the earned value of work performed (Budgeted Cost of Work Performed, BCWP) for those tasks in progress to the Actual Cost of the Work Performed (ACWP) and the predicted cost of the work that was scheduled to have been completed (Budgeted Cost of Work Scheduled, BCWS) at the present point in a project schedule. A cost variance is a difference between the BCWP and the ACWP; a schedule variance is a difference between BCWP and the BCWS [*ibid.*:430].

If, for example, at week 21 of the SSTRO, the project has the earned value chart in Figure 15, the project is on cost, but behind schedule:

$$\text{CostVariance} = \text{BCWP} - \text{ACWP} = 89 - 89 = 0$$

$$\text{ScheduleVariance} = \text{BCWP} - \text{BCWS} = 66 - 89 = -23$$

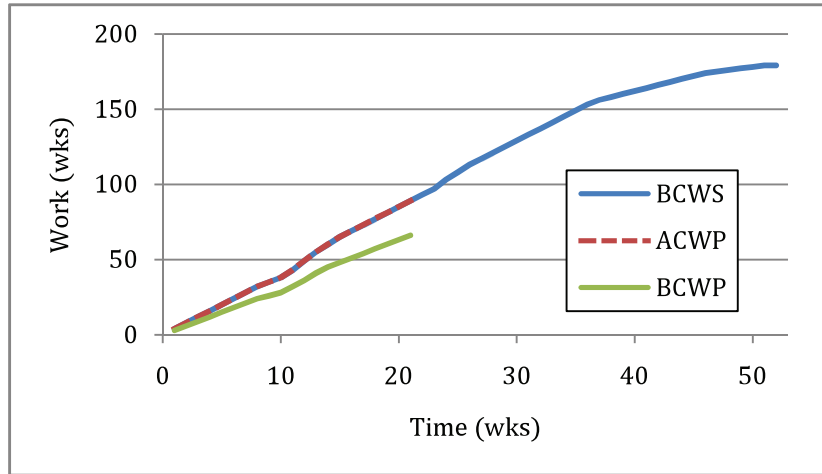


Figure 15 Earned Value Chart

While each project’s duration and percent complete are often rough estimates, having the project schedule gives the decision maker a baseline to plan by and against which to measure progress. Other project management monitoring tools and metrics can be applied — see Meredith and Mantel [2000], Kerzner [2003], and other project management references for specific details.

4.5 Summary

In this chapter, the expanded MM-GPR-RCPS was applied to a notional reconstruction project. It was shown that the model produces feasible solutions and that each preemptive goal improves the solution with respect to that goal without effecting the solution’s satisfaction of higher priority goals. The model allows alternative priorities and policies to be investigated so plans can be evaluated. Monitoring is enabled by the use of any project management tools available.

While three goals were illustrated in this example, the goal programming modeling framework allows a range of goals, priorities, and policies to be considered, as dictated by the individual operational setting. The level of granularity of the model will depend on the information and computational power available.

The next chapter will present the research conclusions and suggest future avenues of related research.

V. Conclusions and Future Research

5.1 *Research Conclusions*

This research developed a goal-programming-based, resource-constrained project scheduling approach to planning for the initial response phase of post-conflict stabilization, security, transition, and reconstruction operations. The relevant literature on post-conflict reconstruction, project scheduling, and goal programming was reviewed. From this review, the conclusion was drawn that preference should be given to activities which make use of the local workforce when planning reconstruction activities.

With this conclusion in mind, an illustrative model was developed which includes three goals: meeting timely deadlines for restoring essential services; distributing employment equitably among regions in the area of operations; and meeting standards for sustainable incomes in each region. The solution presented allows the reconstruction authority to schedule their activities with a mind towards the ultimate recovery of the region while still meeting the requirements of the initial response. This model was then applied to a notional scenario to show how it can be applied to an SSTR operation. By including an array of objective goals and priorities, the model allows the investigation of varying SSTRO settings. Indeed, it could be applied to any type of stabilization operation where development and employment are to be considered.

In conclusion, this paper makes two main points. First, SSTRO plans should consider the economic impact of reconstruction activities. The United States Government Interagency Counterinsurgency Initiative's *U.S. Government Counterinsurgency Guide* affirms the importance of economic considerations in stabilization operations: stating that COIN operations seek

. . . to provide essential services and stimulate long term economic growth, thereby generating confidence in the government while at the same time reducing the pool of frustrated, unemployed young men and women from which insurgents can readily recruit [USGICI 2009:3].

Second, to facilitate effective execution of reconstruction activities, quantitative project scheduling techniques can, and should, be applied to SSTRO. No amount of planning will replace competent commanders on the ground: as General Field Marshall Helmuth von Moltke famously remarked, “. . . no plan of operations extends with any certainty beyond the first contact with the main hostile force” [Keyes 2006:xi]. However, a project schedule forms a baseline by which any SSTRO can be planned for and measured against. Using sound analytical processes, different SSTRO strategies can be compared. Sensitivity analysis can be conducted to explore the effect of different parameters on the schedule of reconstruction activities. Further, the use of established project management techniques allows the use of established project management tracking tools. To wit, using sound management practices adds quantitative defensibility to an SSTRO plan and can uncover shortfalls or other problems.

5.2 Future Research

This research is a step towards the employment of sound project management techniques in the post-conflict environment. Using this study as a starting point, several directions of future research suggest themselves.

First, this model limits itself to restoring essential infrastructure during the initial response phase of SSTRO. A useful project would be to extend the planning horizon to include the S/CRS’s Transformation and Fostering Sustainability phases of SSTRO. The model could account for long-term improvements in social welfare or other appropriate measures.

In addition to extending the planning horizon, future research could broaden

the scope of the model to include tasks outside the sector of Economy and Infrastructure that were used in this introductory analysis. Indeed the formulation of a broader, more-holistic social welfare function for use in SSTRO would be a worthwhile effort. Alternatively, the model could be extended to provide output in a format compatible with MPICE goals and measures.

Second, the development of a heuristic to generate solutions quickly for medium- to large-sized problems would be worthwhile. For realistically sized RCPSP instances, a heuristic may execute in a more operationally feasible time than computing exact solutions. De Reyck and Herroelen use a Tabu search method to find good solutions for the MM-RCPSP-GPR [1999]. Several constructive heuristics for the RCPSP exist [Artigues and Riveau 2008]. Extending a heuristic to account for the economic goals of this model could allow faster generation of solutions for larger problem instances. This may be particularly justified when the parameters are known to be estimates at best.

Third, Demeulemeester, Herroelen, and others have done significant research in the field of schedule robustness — creating schedules which minimize the probability of activities starting after their scheduled start times under uncertain activity durations or uncertain resource levels. SSTRO activities generally have significant uncertainty that is not accounted for by the MM-RCPSP-GPR model. Adding proactive/reactive procedures to the schedule generation scheme could help meet the National Science and Technology Council’s goal of developing techniques to manage risk in infrastructure reconstruction [NSTC 2008:15] Allowing the user to manually delay an activity’s start or finish time would help planners understand the interrelations between activities and the cascading effect such a perturbation might have.

Finally, this model could be used to augment other SSTRO analysis packages. If the planning horizon were extended, this scheduling approach could provide closer detail of project execution modes. For example, this model could pro-

vide details on government hiring rates and infrastructure levels for the Labor Market submodel and Critical Infrastructure submodel of Richardson's systems dynamics SSTRO model, it could augment Robbins' region-level systems model [2005] with subregional activity execution information, or it could provide additional detail to AFRL's National Operational Environment Model (NOEM) model. Further, if the model included stochastic elements and proactive/reactive scheduling, it could run within another simulation to provide timing information on specific projects within the overall stabilization operation.

Any of these avenues would be valuable further steps towards sound project management in post-conflict environments. The use of these techniques will allow better planning for and tracking of SSTRO; and reactive techniques will allow better responses to changes in the planning environment. These studies would give future military planners tools for modeling the full spectrum of conflict in which the modern military operates.

Bibliography

1. Artigues, Christian. "The Resource-Constrained Project Scheduling Problem," in *Resource Constrained Project Scheduling: Models, Algorithms, Extensions and Applications*. Eds. Christian Artigues, Sophie Demasse, and Emmanuel Néron. Hoboken NJ: John Wiley & Sons, Inc., 2008.
2. Artigues, Christian and David Riveau. "Heuristics," in *Resource Constrained Project Scheduling: Models, Algorithms, Extensions and Applications*. Eds. Christian Artigues, Sophie Demasse, and Emmanuel Néron. Hoboken NJ: John Wiley & Sons, Inc., 2008.
3. Beale, E. M. L. and J. J. H. Forrest. "Global Optimization Using Special Ordered Sets." *Mathematical Programming*, 10(1):5269, 1976.
4. Bellenguez-Morineau, Odile and Emmanuel Néron. "Multi-Mode and Multi-Skill Project Scheduling Problem," in *Resource Constrained Project Scheduling: Models, Algorithms, Extensions and Applications*. Eds. Christian Artigues, Sophie Demasse, and Emmanuel Nron. Hoboken NJ: John Wiley & Sons, Inc., 2008.
5. Bergson, Abram. "A Reformulation of Certain Aspects of Welfare Economics." *Quarterly Journal of Economics*, 310–334 (February 1938).
6. Binnendijk, Hans and Stuart E. Johnson, Ed., *Transforming for Stabilization and Reconstruction Operations*, Center for Technology and National Security Policy, National Defense University, Washington DC, April 2004.
7. Blazewicz, J., J.K. Lenstra, A.H.G. Rinnooy Kan. "Scheduling subject to resource constraints: classification and complexity." *Discrete Applied Mathematics*, 5: 11-24 (January 1983).
8. Bush, George W. *Management of Interagency Efforts Concerning Reconstruction and Stabilization*. National Security Presidential Directive 44. Washington DC: 7 Dec 2005.
9. Charnes, A., W.W. Cooper, and R.O. Ferguson. "Optimal Estimation of Executive Compensation by Linear Programming." *Management Science*, 1:138-151 (January 1955).
10. Covey, Jack, Michael Dziedzic, and Leonard Hawley, Ed., *The Quest for Viable Peace*, Washington DC: United States Institute of Peace Press, 2005.
11. Deckro, R.F., J.E. Hebert, and W.A. Verdini. "Project Scheduling with Work Packages." *OMEGA International Journal of Mangement Science*, 20: 169-182 (1992).
12. Demeulemeester, Erik L. and Willy S. Herroelen. *Project Scheduling: A Research Handbook*. Boston: Kluwer Academic Publishers, 2002.

13. De Reyck, Bert and Willy Herroelen. "The multi-mode resource-constrained project scheduling problem with generalized precedence relations." *European Journal of Operational Research*, 119: 538-556 (1999).
14. Department of Defense. *Military Support for Stability, Security, Transition, and Reconstruction (SSTR) Operations*. DoD Directive 3000.05. Washington DC: GPO, 28 November 2005.
15. Department of State. *Reconstruction and Stabilization: U.S. Foreign Policy Interests*. 10 November 2004. <http://www.state.gov/s/crs/rls/38033.htm>, accessed 9 August 2008.
16. Department of State. *Post-Conflict Reconstruction Essential Tasks*. S/CRS. April 2005.
17. Fleurbaey, Marc and Philippe Mongin. "The news of the death of welfare economics is greatly exaggerated." *Social Choice and Welfare*, 25:381-418 (December 2005).
18. Fredley, M.L. *A Decomposition Approach for the Multi-Modal, Resource-Constrained, Multi-Project Scheduling Problem with Generalized Precedence and Expediting Resources*. Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 2001.
19. Ghani, Ashraf and Clare Lockhart. *Fixing Failed States*, New York: Oxford University Press, 2008.
20. Hagstrom, J.N. "Computational complexity of PERT problems." *Networks*, 18:139-147 (1988).
21. Haims, Marla C, David Gompert, Gregory Treverton, and Brooke Stearns. "Breaking the Failed-State Cycle." RAND Corporation, 2008.
22. Hartmann, Sönke and Andreas Drexl. "Project Scheduling with Multiple Modes: A Comparison of Exact Algorithms." *Networks*, 32:283-297 (1998).
23. Heilmann, Roland. "A branch-and-bound procedure for the multi-mode resource-constrained project scheduling problem with minimum and maximum time lags." *European Journal of Operational Research*, 144:348-365 (2003).
24. Heldt, Birger. "Trends from 1948 to 2005: How to View the Relation between the United Nations and Non-UN Entities," in *Peace Operations: Trends, Progress, and Prospects*. Eds. Donald C.F. Daniel, Patricia Taft, and Sharon Wiharta. Washington DC: Georgetown University Press, 2008.
25. Henderson, James M. "Local Government Expenditures: A Social Welfare Analysis." *Review of Economics & Statistics*, 50:156-163 (May 1968).
26. Kemp M.C., Y.K. Ng "On the existence of social welfare functions, social orderings and social decision functions." *Economica*, 43:596-611 (1976).

27. Kerzner, Harold. *Project Management : A Systems Approach to Planning, Scheduling, and Controlling*. 8th ed. Hoboken NJ: John Wiley, 2003.
28. Keyes, Ralph. *The Quote Verifier: Who Said What, Where, and When* [1st Edition]. St. Martin's Griffin, May 30, 2006.
29. Meredith, Jack R. and Samuel J. Mantel, Jr. *Project Management: A Managerial Approach*. Fourth Edition. New York NY: John Wiley & Sons, Inc., 2000.
30. Néron, Emmanuel. "Branching Schemes for Branch-and-Bound," in *Resource Constrained Project Scheduling: Models, Algorithms, Extensions and Applications*. Eds. Christian Artigues, Sophie Demasse, and Emmanuel Néron. Hoboken NJ: John Wiley & Sons, Inc., 2008.
31. National Science and Technology Council. "Research & Development Challenges for Regional Stability and Capacity Building," Washington DC, February 2008.
32. Parks, R. "An impossibility theorem for fixed preferences: a dictatorial Bergson-Samuelson welfare function." *Rev Econ Stud* 43:447-450 (1976).
33. Pascual, Carlos. Vice President and Director for Foreign Policy Studies at the Brookings Institution. "Building Capacity for Stabilization & Reconstruction." Testimony for House Armed Services Subcommittee on Oversight & Investigations, US Congress. 29 January 2008.
34. Pritchard, Carl L. *How to build a Work Breakdown Structure: The Cornerstone of Project Management*. Arlington VA: ESI International, 1998.
35. Pritsker, Alan B., Lawrence J. Watters, and Philip M. Wolfe. "Multiproject Scheduling with Limited Resources: A Zero-One Programming Approach." *Management Science*, 16:93-108 (September 1969).
36. Rice, Condoleezza. "The Promise of Democratic Peace: Why Promoting Freedom Is the Only Realistic Path to Security." *The Washington Post*, 11 December 2005, B07.
37. Rothenberg, Jerome. *The Measurement of Social Welfare*. Englewood Cliffs NJ: Prentice-Hall, Inc., 1961.
38. Schniederjans, Marc J. *Goal Programming: Methodology and Applications*, Boston MA: Kluwer Academic Publishers, 1995.
39. Sphere Project, The. *Humanitarian Charter and Minimum Standards in Disaster Response*. Oxford: Oxfam Publishing, 2004.
40. Sprecher, Arno and Andreas Drexler. "Multi-mode resource-constrained project scheduling by a simple, general and powerful sequencing algorithm." *European Journal of Operational Research*, 107: 431-450 (1998).

41. United States Government Interagency Counterinsurgency Initiative. *U.S. Government Counterinsurgency Guide*. Bureau of Political-Military Affairs, Department of State. Washington DC: 13 January 2009.
42. United States Institute of Peace. "Peacebuilding Toolkit," August 2007.
43. United States Institute of Peace. "Metrics Framework for Assessing Conflict Transformation and Stabilization," February 2008. <http://www.usip.org/peaceops/mpice.pdf>. Accessed 11 February 2009.
44. U.S. Joint Chiefs of Staff. *Doctrine for Joint Operations*. Joint Publication 3-0. Washington DC: 13 February 2008.
45. U.S. Joint Chiefs of Staff. *Joint Doctrine for Military Operations Other Than War*. Joint Publication 3-07. Washington DC: 16 June 1995.
46. Wansbeek, Tom and Arie Kapteyn. "Tackling Hard Questions by Means of Soft Methods: The Use of Individual Welfare Functions in Socio-Economic Policy." *Kyklos*, 36:249-269 (1983).
47. van Praag, Bernard M.S., "The welfare function of income in Belgium: An empirical investigation." *European Economic Review*, 2:337 (1971).
48. Wiley, Victor D. *Optimization Analysis for Design and Planning of Multi-Project Programs*. AFIT/GOR/ENS/96M-18. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1996.
49. Wiley, Victor D., Richard F. Deckro, and Jack A. Jackson, Jr., "Optimization analysis for design and planning of multi-project programs." *European Journal of Operational Research*, 107:492-506, 1998.

Appendix A. S/CRS Immediate Response Tasks Work Breakdown Structure

Included here are the Initial Response tasks from the State Department's Office of the Coordinator of Reconstruction and Stabilization's Post-Conflict Reconstruction Essential Tasks list [<http://www.crs.state.gov>] translated into a Work Breakdown Structure.

Sectoral tasks outside Economic Stabilization and Infrastructure that have an infrastructure implication are highlighted with grey shading.

A.1 Security

The first portion of the WBS includes those tasks relating to establishing a safe and secure environment[DoS 2005:I-1].

1. SECURITY

- 1.1. Disposition of Armed and Other Security Forces, Intelligence Services and Belligerents
 - 1.1.1. Cessation of Hostilities
 - 1.1.1.1. Enforce ceasefires
 - 1.1.1.2. Supervise disengagement of belligerent forces
 - 1.1.1.3. Identify and neutralize potential spoilers
 - 1.1.1.4. Negotiate terms for exchange of prisoners of war
 - 1.1.1.5. Engage indigenous forces capable of promoting immediate stability
 - 1.1.2. Enforcement of Peace Agreements and/or Other Arrangements
 - 1.1.2.1. Provide security for negotiations among indigenous belligerents
 - 1.1.2.2. Develop confidence-building measures between indigenous belligerents
 - 1.1.2.3. Conduct counterinsurgency operations
 - 1.1.3. Disposition and Constitution of National Armed Services
 - 1.1.3.1. Implement plan for disposition of indigenous armed forces and other national security institutions
 - 1.1.3.2. Identify future roles, missions and structure
 - 1.1.3.3. Vet senior officers and other individuals for past abuses
 - 1.1.3.4. Coordinate and integrate with DDR plans
 - 1.1.4. Disarmament
 - 1.1.4.1. Negotiate arrangements with belligerents
 - 1.1.4.2. Establish and enforce weapons control regimes, including collection and destruction
 - 1.1.4.3. Identify international arms dealers
 - 1.1.4.4. Provide reassurances and incentives for disarmed faction
 - 1.1.4.5. Establish monitoring regime
 - 1.1.5. Demobilization
 - 1.1.5.1. Establish demobilization camps
 - 1.1.5.2. Ensure adequate health, food provisions, and security for belligerents
 - 1.1.6. Reintegration of Combatants
 - 1.1.6.1. Design reintegration strategy, including assessment of absorptive capacity of economic and social sectors
 - 1.1.6.2. Provide jobs, pensions or other material support for demobilized forces
 - 1.1.6.3. Coordinate with overall political and economic recovery plans
 - 1.1.7. Disposition and Constitution of National Intelligence Service(s)
 - 1.1.7.1. Implement plan for disposition of indigenous intelligence services and other national security institutions
 - 1.1.7.2. Identify future roles, missions and structure
 - 1.1.7.3. Vet individuals for past abuses and activities
 - 1.1.7.4. Coordinate and integrate with DDR plans
- 1.2. Territorial Security
 - 1.2.1. Border and Boundary Control
 - 1.2.1.1. Establish border security, including customs regime to prevent arms smuggling, interdict contraband (i.e., drugs and natural resources), prevent trafficking of persons, regulate immigration and emigration, and establish control over major points of entry
 - 1.2.2. Freedom of Movement
 - 1.2.2.1. Establish and disseminate rules relevant to movement
 - 1.2.2.2. Facilitate internal travel of key leaders
 - 1.2.2.3. Dismantle roadblocks and establish checkpoints
 - 1.2.2.4. Regulate air and overland movement
 - 1.2.2.5. Ensure freedom of movement
 - 1.2.3. Identification Issues
 - 1.2.3.1. Establish identification regime including securing documents relating to personal identification, property ownership, court records, voter registries, birth certificates and driving licenses
- 1.3. Public Order and Safety
 - 1.3.1. Protection of Non-Combatants
 - 1.3.1.1. Protect vulnerable elements of population (refugees, IDP, women, children)

[DoS 2005]

- 1.3.1.2. Ensure humanitarian aid and security force access to endangered populations and refugee camps
- 1.3.2. Interim Policing
 - 1.3.2.1. Perform civilian police functions including investigating crimes and making arrests
 - 1.3.2.2. Supervise incarceration processes and transfer to prison facilities
- 1.3.3. Controlling Crowds and Disturbances Control
 - 1.3.3.1. Control crowds, prevent looting and manage civil disturbances
 - 1.3.3.2. Conduct special police operations requiring formed units, including investigations and arrests
- 1.3.4. Clearance of UXO
 - 1.3.4.1. Conduct emergency de-mining and UXO removal
 - 1.3.4.2. Conduct mapping and survey exercises of mined areas
 - 1.3.4.3. Mark mine fields
 - 1.3.4.4. Identify and coordinate emergency requirements
 - 1.3.4.5. Establish priorities and conduct de-mining operations
- 1.4. Protection of Indigenous Individuals, Infrastructure and Institutions
 - 1.4.1. Private Institutions and Key Leaders
 - 1.4.1.1. Protect key political and societal leaders
 - 1.4.1.2. Protect and secure places of religious worship and cultural sites
 - 1.4.1.3. Protect private property and factories
 - 1.4.2. Critical Facilities
 - 1.4.2.1. Protect and secure critical infrastructure, natural resources, civil registries, property ownership documents
 - 1.4.2.2. Secure records, storage, equipment and funds related to criminal justice and security institutions
 - 1.4.3. Military Facilities
 - 1.4.3.1. Identify, secure and protect stockpiles of conventional, nuclear, biological, radiological and chemical materials
 - 1.4.3.2. Secure military depots, equipment, ammunition dumps and means of communication
 - 1.4.4. Public Institutions
 - 1.4.4.1. Protect and secure strategically important institutions (e.g., government buildings, museums, religious sites, courthouses, communications, etc.)
 - 1.4.5. Witness and Evidence Protection
 - 1.4.5.1. Locate and safeguard key witnesses, documents and other evidence related to key ongoing or potential U.S. investigations and prosecutions
- 1.5. Protection of Reconstruction and Stabilization Personnel and Institutions
 - 1.5.1. Official Civilian Stabilization and Reconstruction Personnel and Facilities
 - 1.5.1.1. Protect government-sponsored civilian stabilization and reconstruction personnel
 - 1.5.1.2. Provide logistical support to sustain them in the field
 - 1.5.2. Contractor and NGO Stabilization and Reconstruction Personnel and Facilities
 - 1.5.2.1. Protect contractor and NGO stabilization personnel and resources
 - 1.5.2.2. Provide logistical support
- 1.6. Security Coordination
 - 1.6.1. International Security Forces
 - 1.6.1.1. Develop integrated command, control and intelligence (C2I) and information sharing arrangements between international military, constabulary and civilian police forces
 - 1.6.1.2. Determine rules of engagement; clearly define roles and responsibilities, including custody/transfer of detainees
 - 1.6.2. Intelligence Support
 - 1.6.2.1. Provide integrated intelligence support for international military, constabulary and civilian police forces
 - 1.6.3. Coordination with Indigenous Security Forces
 - 1.6.3.1. Develop coordinated C2I arrangements between international and indigenous security forces
 - 1.6.4. International Civilian-Military Coordination
 - 1.6.4.1. Develop coordinated military and civilian C2I and information sharing arrangements
 - 1.6.5. Regional Security Arrangements
 - 1.6.5.1. Negotiate or modify regional security arrangements with all interested parties

[DoS 2005]

- 1.6.5.2. Negotiate the enhancement of cross border controls and security
- 1.6.5.3. Consult with neighboring countries on border security plans
- 1.7. Public Information and Communications
 - 1.7.1. Disseminate Security Information
 - 1.7.1.1. Identify or establish outlets for international, national, and local news media
 - 1.7.1.2. Utilize media as public information tool to provide factual information and control rumors
 - 1.7.1.3. Issue effective press releases and timely provision of information services as needed in local languages
 - 1.7.1.4. Assist National Transitional Administration and/or National Government to inform public regularly

[DoS 2005]

A.2 Governance and Participation

The second portion includes tasks relating to determining governance structure and establishing a foundation for citizen participation [DoS 2005:II-1].

2. GOVERNANCE AND PARTICIPATION

- 2.1. National Constituting Processes
 - 2.1.1. National Dialogue
 - 2.1.1.1. Establish process at national, regional, and/or local levels to represent views of citizenry, consider political pressures and interests
 - 2.1.2. Constitution
 - 2.1.2.1. Work with indigenous actors to establish constitutional commission and determine method of adoption
 - 2.1.2.2. Provide technical and legal advisors with expertise on key issues in constitutional process (regional, ethnic, and religious; division of powers)
- 2.2. Transitional Governance
 - 2.2.1. International Transitional Administration
 - 2.2.1.1. Determine need for international transitional administration
 - 2.2.1.2. Establish transitional political authority; and interim civil administration, placing advisors into key Ministries and local governments
 - 2.2.1.3. Vet indigenous officials and reconstitute leadership at multiple levels of government
 - 2.2.1.4. Deliver administrative support systems
 - 2.2.2. National Transitional Administration
 - 2.2.2.1. Establish rules and realistic timetable for interim national government
 - 2.2.2.2. Work with indigenous leaders to recruit individuals to serve on and advise the national transitional government
 - 2.2.2.3. Establish process for passing and amending interim laws and regulations
- 2.3. Executive Authority
 - 2.3.1. Executive Mandate and Structure
 - 2.3.1.1. Prioritize government functions
 - 2.3.1.2. Identify unmet institutional needs
 - 2.3.1.3. Determine structure and affordable size of civil service to meet immediate and future needs
 - 2.3.2. Civil Service Staffing
 - 2.3.2.1. Develop transparent process to vet executive officials, civil servants and employees of state owned enterprises and to identify individuals to receive training
 - 2.3.2.2. Encourage members of the diaspora with leadership skills to return to country
 - 2.3.3. Revenue Generation and Management
 - 2.3.3.1. Assess mechanism for generating and managing revenue at different levels of government
 - 2.3.3.2. Establish anti-corruption measures for sources prone to misuse, especially extractive industries and state-owned enterprises
 - 2.3.3.3. Coordinate resources across levels of government
 - 2.3.4. Government Resources and Facilities
 - 2.3.4.1. Establish basic facilities to enable National Transitional Infrastructure Administration to function
- 2.4. Legislative Strengthening
 - 2.4.1. Mandate
 - 2.4.1.1. Establish interim legislative process
 - 2.4.1.2. Establish authority of legislative branch to participate in national policy-making process and provide oversight of executive authority
 - 2.4.2. Citizen Access
 - 2.4.2.1. Identify legal, institutional, and political obstacles affecting citizens' input to legislative process
 - 2.4.3. Staffing and Training
 - 2.4.3.1. Provide training and support for provisional lawmakers
 - 2.4.4. Resources and Facilities
 - 2.4.4.1. Assure the initial lawmaking process is adequately resourced
- 2.5. Local Governance
 - 2.5.1. Local Governance Mandate
 - 2.5.1.1. Restore essential local public services
 - 2.5.1.2. Establish mechanisms for local level participation, taking into account history and culture
 - 2.5.1.3. Establish temporary liaison process between national and local governing institutions

[DoS 2005]

- 2.5.2. Staffing and Training
 - 2.5.2.1. Develop transparent process to vet local officials and civil servants
 - 2.5.2.2. Initiate local service delivery training and support
- 2.5.3. Services, Resources and Facilities
 - 2.5.3.1. Assure resources for personnel, supplies, and equipment to deliver essential local services
 - 2.5.3.2. Identify, rehabilitate, secure, and maintain basic facilities to enable delivery of essential local services
- 2.6. Transparency and Anti-Corruption
 - 2.6.1. Anti-Corruption
 - 2.6.1.1. Provide legal advisors and consultants
 - 2.6.1.2. Create mechanisms to curtail corruption across government institutions
 - 2.6.1.3. Design and implement anti-corruption campaign, including education
 - 2.6.1.4. Mainstream anti-corruption efforts into other programs
 - 2.6.1.5. Develop agreement and mechanisms for dealing with past abuses
 - 2.6.1.6. Seek international cooperation to combat corruption
 - 2.6.2. Oversight
 - 2.6.2.1. Encourage formation of watchdog organizations in public and private sectors to monitor international and national institutions
- 2.7. Elections
 - 2.7.1. Elections Planning and Execution
 - 2.7.1.1. Set realistic timetable, goals, and budget for elections
 - 2.7.1.2. Facilitate indigenous decision on the mode of representation and sequence of elections (national/local)
 - 2.7.1.3. Determine identification requirements for registration/voting
 - 2.7.1.4. Establish independent national electoral commission
 - 2.7.1.5. Establish or verify voter registry
 - 2.7.2. Elections Monitoring
 - 2.7.2.1. Secure agreements for international and domestic monitoring presence
 - 2.7.3. Elections Outreach
 - 2.7.3.1. Enable electoral commission to publicize election timetable and encourage citizen participation
 - 2.7.3.2. Gauge public opinion through polling
- 2.8. Political Parties
 - 2.8.1. Party Formation
 - 2.8.1.1. Support political competition
 - 2.8.1.2. Ensure clear legal status, protections, and regulations of political parties
 - 2.8.2. Party Training
 - 2.8.2.1. Identify and assess capabilities of potential political party leaders and structures
- 2.9. Civil Society and Media
 - 2.9.1. Civil Society Environment
 - 2.9.1.1. Review existing regulations on NGOs and civil society actors
 - 2.9.1.2. Identify and assess civil society actors, their roles in the conflict, membership and capacity
 - 2.9.2. Civic Education
 - 2.9.2.1. Establish civic education and public education campaigns to raise awareness and understanding of new political structure, human rights, tolerance and other issues
 - 2.9.3. Strengthening Capacity and Partnerships
 - 2.9.3.1. Provide support to civil society to deliver services, promote democracy and tolerance, and give voice to concerns of vulnerable populations
 - 2.9.3.2. Encourage inter-group partnerships and community building functions at the local level
 - 2.9.3.3. Link these efforts to national governance initiatives
 - 2.9.4. Professionalism and Ethics
 - 2.9.4.1. Institute short-term training for journalists, editors, government spokespersons, and other media professionals
 - 2.9.5. Media Business Development
 - 2.9.5.1. Train media managers, advertising department staff, and business consultants

[DoS 2005]

- 2.9.5.2. Provide small grants and low interest loans for start-ups and/or rebuilding
- 2.9.6. Media Environment
 - 2.9.6.1. Develop regulatory environment for use of access to the media
 - 2.9.6.2. Ensure appropriate balance between government and independent media
 - 2.9.6.3. Support monitoring of media rights violations as well as of inflammatory or unprofessional media contents
- 2.10. Public Information and Communications
 - 2.10.1. Disseminate Governance Information
 - 2.10.1.1. Identify or establish outlets for international, national, and local news media
 - 2.10.1.2. Utilize media as public information tool to provide factual information and control rumors
 - 2.10.1.3. Issue effective press releases and timely provision of information services as needed in local languages
 - 2.10.1.4. Assist National Transitional Administration and/or National Government to inform public regularly

[DoS 2005]

A.3 Humanitarian Assistance and Social Well-being

The third portion includes tasks relating to providing for emergency humanitarian needs [DoS 2005:III-1].

3. HUMANITARIAN ASSISTANCE AND SOCIAL WELL-BEING

3.1. Refugees and Internally Displaced Persons (IDPs)

3.1.1. Prevention of Population Displacements

- 3.1.1.1. Ensure humanitarian access to populations in need
- 3.1.1.2. Assess total food needs for affected populations
- 3.1.1.3. Determine the reliability of local market channels; assess availability of local supplies to meet needs
- 3.1.1.4. Be aware of local crop cycles so that local supplies can be used to feed populations and to ensure that food aid deliveries do not interfere with local purchases and markets
- 3.1.1.5. Assess the adequacy of local physical transport, distribution and storage facilities
- 3.1.1.6. Estimate food aid needs for affected populations
- 3.1.1.7. Assess personnel requirements to facilitate the provision of humanitarian needs
- 3.1.1.8. Provide emergency food, water, sanitation, shelter, and medicine
- 3.1.1.9. Maintain freedom of movement and ensure borders are open to potential refugees
- 3.1.1.10. Coordinate with other donors and humanitarian agencies

3.1.2. Refugee Assistance

- 3.1.2.1. Urge asylum countries to keep borders open to refugees
- 3.1.2.2. Establish registration and screening mechanisms
- 3.1.2.3. Assess total food needs for affected populations
- 3.1.2.4. Determine the reliability of local market channels; assess availability of local supplies to meet needs
- 3.1.2.5. Be aware of local crop cycles so that local supplies could be used to feed populations and to ensure that food aid deliveries do not interfere with local purchases and markets
- 3.1.2.6. Assess the adequacy of local physical transport, distribution and storage facilities
- 3.1.2.7. Assess personnel requirements to facilitate the provision of humanitarian needs
- 3.1.2.8. Estimate food aid needs for refugees.
- 3.1.2.9. Provide humanitarian assistance including emergency food, water, sanitation, shelter, and medicine. Pay special attention to the needs of vulnerable groups, including women, children and the elderly
- 3.1.2.10. Maintain freedom of movement and ensure borders are open to potential refugees
- 3.1.2.11. Coordinate with other donors and humanitarian agencies
- 3.1.2.12. Where no other options exist, establish camps that recognize physical, economic, social, and security considerations
- 3.1.2.13. Implement information campaign to keep refugees informed
- 3.1.2.14. Ensure adequate protection and monitoring in the countries of origin and asylum

3.1.3. Internally Displaced Persons (IDPs) Assistance

- 3.1.3.1. Ensure freedom of movement to the greatest extent possible
- 3.1.3.2. Establish registration and monitoring mechanisms
- 3.1.3.3. Promote traditional coping mechanisms (e.g., homestays)
- 3.1.3.4. Provide assistance to families and communities hosting IDPs
- 3.1.3.5. Establish IDP camps if necessary and provide basic humanitarian assistance
- 3.1.3.6. Assess total food needs for affected populations
- 3.1.3.7. Determine the reliability of local market channels; assess availability of local supplies to meet needs
- 3.1.3.8. Ensure that food aid deliveries do not interfere with local production and markets;
- 3.1.3.9. Track local crop cycles and to the extent feasible, produce food supplies locally
- 3.1.3.10. Assess the adequacy of local physical transport, distribution and storage facilities. Assess the desirability of contracting commercial facilities.
- 3.1.3.11. Coordinate with other donors and humanitarian agencies
- 3.1.3.12. Assess personnel requirements to facilitate the provision of humanitarian needs
- 3.1.3.13. Establish public information campaign to inform IDPs

3.1.4. Refugee and IDP Camp Security

- 3.1.4.1. Ensure adequate protection and monitoring
- 3.1.4.2. Ensure humanitarian aid and security force access to endangered populations and refugee camps

[DoS 2005]

- 3.2. Trafficking in Persons
 - 3.2.1. Anti-Trafficking Strategy
 - 3.2.1.1. Assess levels of forms of trafficking in persons in region, sub-regions, and country
 - 3.2.1.2. Collect and analyze data to map trafficking levels and routes
 - 3.2.1.3. Establish benchmarks for measuring trafficking
 - 3.2.1.4. Analyze supply and demand factors to gain insight into economic forces that make trafficking attractive
 - 3.2.1.5. Document the extent of trafficking and sexual exploitation in refugee and conflict situations
 - 3.2.1.6. Develop multifaceted and integrated strategy based on prevention of trafficking, protection and assistance for victims, and prosecution of traffickers
 - 3.2.2. Assistance for Victims
 - 3.2.2.1. Provide assistance to victims of trafficking including rescue, shelter, and access to psychological, legal and medical assistance
 - 3.2.2.2. Establish or support victim hotlines
 - 3.2.2.3. Support programs for victims of conflict-related trafficking, including refugees and IDPs
 - 3.2.2.4. Partner with non-governmental organizations and faith-based institutions that are fighting trafficking and assisting victims of prostitution, child labor, and all forms of slavery
 - 3.2.3. Anti-Trafficking Legislation
 - 3.2.3.1. Assess political will to combat trafficking as evidenced by legislative reform and enforcement, prosecution of traffickers, and cooperation with NGOs, faith-based institutions, and governments to prosecute traffickers
- 3.3. Food Security
 - 3.3.1. Famine Prevention
 - 3.3.1.1. Monitor and analyze food security by conducting livelihood-based food security analyses
 - 3.3.1.2. Disseminate early warning and food security analyses through production of targeted information products
 - 3.3.1.3. Predict the effects of conflict on access to food (e.g., presence of refugees, price of food)
 - 3.3.1.4. Assess serious challenges to response
 - 3.3.2. Emergency Food Relief
 - 3.3.2.1. Conduct rapid food and nutrition assessments with particular attention to: (i) market prices, channels and infrastructure; and (ii) local agricultural production of basic food stuffs, including the harvest cycle
 - 3.3.2.2. Estimate total food needs
 - 3.3.2.3. Coordinate with other donors and humanitarian agencies
 - 3.3.2.4. Assess the adequacy of local physical transport, distribution and storage facilities
 - 3.3.2.5. Secure emergency food aid distribution channels
 - 3.3.2.6. Deliver emergency food (including therapeutic feeding) to most vulnerable populations
 - 3.3.2.7. Supply adequate storage facilities to prevent food contamination
 - 3.3.3. Food Market Response
 - 3.3.3.1. Identify existing markets including market interferences, such as bottlenecks and failures (monopolies, cartels, policy interferences)
 - 3.3.3.2. Identify crop and harvest cycles and traditional trade patterns
 - 3.3.3.3. Conduct market surveys/assessments
 - 3.3.3.4. Assess weather conditions, transportation networks, and storage facilities
- 3.4. Shelter and Non-Food Relief
 - 3.4.1. Non-Food Relief Distribution
 - 3.4.1.1. Conduct rapid non-food needs assessments
 - 3.4.1.2. Secure emergency non-food relief distribution channels
 - 3.4.1.3. Deliver emergency non-food items (plastic sheeting, sundries, blankets, etc.) to most vulnerable populations
 - 3.4.1.4. Protect non-food distribution network
 - 3.4.1.5. Supply adequate storage facilities
 - 3.4.2. Shelter Construction
 - 3.4.2.1. Provide emergency shelter for immediate needs

[DoS 2005]

- 3.4.2.2. Develop housing development strategy to address refugees/IDPs as well as reintegration of ex-combatants
- 3.4.2.3. Link Cash-For-Work activities to jump-start affected economies
- 3.5. Humanitarian Demining
 - 3.5.1. Mine Awareness
 - 3.5.1.1. Teach people how to recognize, avoid, and inform demining authorities of the presences of land mines. Focus efforts on children and young males
 - 3.5.1.2. Utilize a variety of materials and media to convey important messages
 - 3.5.1.3. Be sensitive to the cultural mores of the population (e.g., have women train women in Muslim societies)
 - 3.5.2. Mine Detection
 - 3.5.2.1. Conduct a landmine impact survey to determine the nature and extent of the landmine problem: identify broad areas within the country where mines exist and estimate the extent of the problem.
 - 3.5.2.2. Demarcate mined areas
 - 3.5.2.3. Note the number and types of mines found within the area
 - 3.5.3. Mine Clearance
 - 3.5.3.1. VOID
 - 3.5.4. Survivor Assistance
 - 3.5.4.1. Treat initial injuries
 - 3.5.4.2. Develop survivor assistance strategy
 - 3.5.4.3. Assist with settlement and resettlement of refugees and IDPs who may be endangered by landmines in the course of flight from their homes and subsequent return
- 3.6. Public Health
 - 3.6.1. Potable Water Management
 - 3.6.1.1. Ensure proper quantity of drinking water
 - 3.6.2. Sanitation and Waste Water Management
 - 3.6.2.1. Ensure proper sanitization, purification and distribution of drinking water
 - 3.6.2.2. Provide interim sanitation, wastewater and waste disposal services
 - 3.6.3. Medical Capacity
 - 3.6.3.1. Stockpile and distribute emergency medical supplies and drugs
 - 3.6.3.2. Set up or re-open accessible clinics to deal with emergency health problems (e.g., disease, infection, wounds)
 - 3.6.4. Local Public Health Clinics
 - 3.6.4.1. Evaluate need for new clinics
 - 3.6.4.2. Repair and rebuild clinics
 - 3.6.5. Hospital Facilities
 - 3.6.5.1. Evaluate need for new hospitals
 - 3.6.5.2. Repair and rebuild hospitals
 - 3.6.6. Human Resources Development for Health Care Workforce
 - 3.6.6.1. Recruit doctors, nurses, and staff and community health workers
 - 3.6.7. Health Policy and Financing
 - 3.6.7.1. Evaluate cost and efficiency of health care system to ensure basic health care needs are being met
 - 3.6.8. Prevention of Epidemics
 - 3.6.8.1. Prevent epidemics through immediate vaccinations
 - 3.6.9. HIV/AIDS
 - 3.6.9.1. Assess HIV/AIDS prevalence especially in most vulnerable populations (e.g., IDPs, refugees, military, peacekeepers)
 - 3.6.9.2. Consider immediate preventative measures
 - 3.6.10. Nutrition
 - 3.6.10.1. Assess chronic and acute malnutrition
 - 3.6.10.2. Set up therapeutic feeding centers as necessary for most vulnerable children (e.g., under 5)
 - 3.6.10.3. Provide vitamin A supplements to mothers and children
 - 3.6.11. Reproductive Health

[DoS 2005]

- 3.6.11.1. Assess emergency care needs (e.g., transportation, birthing facilities)
- 3.6.11.2. Provide family planning to most vulnerable population segments
- 3.6.12. Environmental Health
 - 3.6.12.1. Identify most dangerous public health hazards and isolate from public when possible
 - 3.6.12.2. Safeguard/eliminate most dangerous health hazards
- 3.6.13. Community Health Education
 - 3.6.13.1. Support a public information campaign to educate population about crisis-induced health risks
 - 3.6.13.2. Obtain medical educational materials
- 3.7. Education
 - 3.7.1. Human Resources
 - 3.7.1.1. Reopen schools as quickly as possible
 - 3.7.1.2. Use them to reach civil populace with programs
 - 3.7.2. Education—Schools
 - 3.7.2.1. Evaluate need for new schools
 - 3.7.2.2. Build and repair schools
 - 3.7.2.3. Obtain educational materials
 - 3.7.3. Education—Universities
 - 3.7.3.1. Evaluate need for new universities
 - 3.7.3.2. Build and repair universities
 - 3.7.3.3. Obtain educational materials
 - 3.7.4. Curriculum
 - 3.7.4.1. VOID
 - 3.7.5. Literacy Campaign
 - 3.7.5.1. Survey literacy levels and linguistic groups
 - 3.7.5.2. Develop literacy campaign
- 3.8. Social Protection
 - 3.8.1. Social Protection
 - 3.8.1.1. Launch program for social protection and empowerment of vulnerable populations (women, war widows, orphans/street children, sick, elderly, veterans, etc.)
- 3.9. Assessment, Analysis and Reporting
 - 3.9.1. Humanitarian and Social Well-being Assessment, Analysis and Reporting
 - 3.9.1.1. Identify what critical information is needed, where to find it, what are major gaps, and how to share, present and disseminate the information. If possible, conduct this assessment in advance and identify the gaps in data, information and knowledge
 - 3.9.1.2. Collect information that can provide situational awareness (e.g., conditions on the ground; severity indicators; who are affected populations; location and numbers of affected populations; damage assessments; security assessments)
 - 3.9.1.3. Collect information that can provide operational or programmatic information (e.g., logistical access routes; "who's doing what where"; program/financial needs of organizations; who are other donors)
 - 3.9.1.4. Collect information for background knowledge (e.g., history; geography; population demographics and composition; baseline health indicators; political and economic structure and status; infrastructure; and culture of the country)
 - 3.9.1.5. Analyze information in context; relate to other thematic information; evaluate issues and responses; make projections about the future; recommend policies and actions
 - 3.9.2. Census
 - 3.9.2.1. Establish policy dialogue with national planning leaders to plan national census
 - 3.9.2.2. Establish partnership with UN agencies to garner additional donor support
 - 3.9.3. Land Registers
 - 3.9.3.1. Establish policy dialogue with national planning leaders to develop land registration records
 - 3.9.3.2. Establish partnership with UN agencies to garner additional donor support
- 3.10. Public Information and Communications
 - 3.10.1. Disseminate Humanitarian and Social Well-Being Information
 - 3.10.1.1. Identify or establish outlets for international, national, and local news media

[DoS 2005]

- 3.10.1.2. Utilize media as public information tool to provide factual information and control rumors
- 3.10.1.3. Issue effective press releases and timely provision of information services as needed in local languages
- 3.10.1.4. Assist National Transitional Administration and/or National Government to inform public regularly

[DoS 2005]

A.4 Economic Stabilization and Infrastructure

The fourth portion includes tasks relating to responding to immediate infrastructure needs [DoS 2005:IV-1].

4. ECONOMIC STABILIZATION AND INFRASTRUCTURE

4.1. Employment Generation

4.1.1. Public Works Jobs

4.1.1.1. Design initiatives to provide immediate employment, soliciting projects ideas from local communities

4.1.1.2. Create opportunities for young males, including food for work

4.1.2. Micro and Small Enterprise Stimulation

4.1.2.1. Assess skills deficiencies

4.1.3. Skills Training and Counseling

4.1.3.1. Assess and determine immediately employable labor force for appropriate critical and emergency needs

4.2. Monetary Policy

4.2.1. Central Bank Operations

4.2.1.1. Assess capability of Central Bank to conduct essential operations such as make domestic payments and settlements, make int'l payments, prepare balance sheet, issue letters of credit if Central Bank role is required, reconcile and report on Treasury accounts

4.2.1.2. Initiate immediate capacity in Central Bank to conduct essential Central Bank operations

4.2.1.3. Assess need for revising Central Bank Law

4.2.1.4. Review/prepare bank licensing regulations

4.2.2. Macro-Policy and Exchange Rates

4.2.2.1. Begin dialogue with policy makers to identify priorities and assess capacity to undertake basic macro and exchange rate policies

4.2.2.2. Develop basic monetary policy and take needed steps to stabilize prices and manage inflation (i.e., set up currency auction)

4.2.2.3. Develop credible exchange rate policy, review currency status and take needed steps to ensure credibility (i.e., prepare for new currency if needed)

4.2.3. Monetary Audit

4.2.3.1. Determine skill capacity of key central bank individuals, and if necessary facilitate return of diaspora

4.2.3.2. Identify audit capacity of relevant institution

4.2.3.3. Determine baseline for audit

4.2.4. Monetary Statistics

4.2.4.1. Survey statistical capabilities and begin collecting key statistics

4.2.4.2. Set up statistical unit within the Central Bank

4.3. Fiscal Policy and Governance

4.3.1. Fiscal and Macro-Economic Policy

4.3.1.1. Begin dialogue with policy makers to identify priorities and assess capacity to undertake basic fiscal policy

4.3.1.2. Assess immediate fiscal balance and financing gap

4.3.1.3. Take steps to close fiscal gap

4.3.2. Treasury Operations

4.3.2.1. Reestablish government payment mechanisms to pay recurrent and emergency expenditures

4.3.2.2. Establish simple and reliable capacity to process payments, and to record and report payments

4.3.2.3. Identify capacity to absorb and administer grants and foreign funds

4.3.2.4. Initiate simple and reliable system to manage grants and foreign assistance

4.3.3. Budget

4.3.3.1. Develop budget

4.3.3.2. Rationalize revenues and expenditures and establish priorities

4.3.4. Public Sector Investment

4.3.4.1. Prioritize public investment needs

4.3.4.2. Develop a plan to allocate resources

4.3.4.3. Pay civil service arrears

4.3.4.4. Determine structure and affordable size of civil service to meet ongoing and future needs

4.3.4.5. Strengthen ethics regulations

[DoS 2005]

- 4.3.5. Revenue Generation, Tax Administration
 - 4.3.5.1. Identify tax structure and sources of revenue
 - 4.3.5.2. Design an efficient tax structure with a clear collection policy
 - 4.3.5.3. Manage public accounts
- 4.3.6. Customs Reform, Enforcement
 - 4.3.6.1. Assess customs revenues and efficiencies and weaknesses of customs service
 - 4.3.6.2. Identify immediate physical and capacity barriers to import administration
 - 4.3.6.3. Take steps to open borders in a way that reduces incentives for corruption
 - 4.3.6.4. Review and make recommendations on tariffs
- 4.3.7. Tax Policy
 - 4.3.7.1. Determine the efficacy of alternative short-term tax policies (i.e., tax holiday)
 - 4.3.7.2. Identify and implement ST measures to increase revenue as appropriate – cognizant of effects on war torn population
- 4.3.8. Fiscal Audit
 - 4.3.8.1. Identify audit capacity of relevant institution
 - 4.3.8.2. Determine base line data for audit
 - 4.3.8.3. Create or strengthen compliance laws
- 4.4. General Economic Policy
 - 4.4.1. Strategy/Assessment
 - 4.4.1.1. Survey economic situation (needs assessment), including assessment of absorptive capacity of economic and social sector, financial imbalances, and real sector distortions
 - 4.4.1.2. Formulate assistance strategy in close cooperation with national government /indigenous actors and international community
 - 4.4.1.3. Identify priority sectors for reconstruction and rehabilitation, focusing on the most urgent requirements
 - 4.4.2. Prices and Subsidies
 - 4.4.2.1. Evaluate subsidized sectors, industries, and firms
 - 4.4.2.2. Prepare recommendation and timetable on elimination of subsidies and price controls
 - 4.4.3. International Financial Assistance—Donor Coordination
 - 4.4.3.1. Establish relations with international donor community
 - 4.4.3.2. Address constraints to engagement with IFI community, (i.e., USG legislative sanctions) and take steps to become a member if not already
 - 4.4.3.3. Assist national government in formulating recovery plan
 - 4.4.3.4. Develop mechanism for donor and in-country coordination
 - 4.4.3.5. Complete needs assessment
 - 4.4.3.6. Hold donor conferences to mobilize resources
 - 4.4.4. Public Sector Institutions
 - 4.4.4.1. Identify operational capacity, including physical structure and security
- 4.5. Financial Sector
 - 4.5.1. Banking Operations
 - 4.5.1.1. If banking sector operational, start up commercial banking operations, i.e., open LOC mechanism and trade credits to reintegrate into the international financial community
 - 4.5.1.2. If banking sector operational, ensure capacity for bank payments and settlements
 - 4.5.1.3. Evaluate condition of banks and determine medium-term strategy for operations
 - 4.5.2. Banking Regulations and Oversight
 - 4.5.2.1. Evaluate the regulatory framework
 - 4.5.2.2. Review and prepare bank licensing standards and procedures
 - 4.5.3. Banking Law
 - 4.5.3.1. Review/prepare banking law and determine viability vis-à-vis international standards
 - 4.5.4. Bank Lending
 - 4.5.4.1. Provide immediate credit including access to micro and SME lending
 - 4.5.4.2. Ensure standard banking practices to approve loans are part of early credit programs
 - 4.5.5. Asset and Money Laundering
 - 4.5.5.1. Freeze accounts of combatants

[DoS 2005]

- 4.5.5.2. Block international access of overseas accounts, money laundering
- 4.5.6. Non-Banking Sector
 - 4.5.6.1. VOID
- 4.5.7. Stock and Commodity Markets
 - 4.5.7.1. VOID
- 4.6. Debt
 - 4.6.1. Debt Management
 - 4.6.1.1. Evaluate external position vis-à-vis external and domestic creditors and clear arrears, where possible
 - 4.6.1.2. Establish short-term and MLT debt strategy
 - 4.6.2. Arrears Clearance
 - 4.6.2.1. Conduct inventory of multilateral and bilateral arrears to creditors
 - 4.6.2.2. Develop arrears clearance strategy (i.e., multilateral fund, debt forgiveness)
- 4.7. Trade
 - 4.7.1. Trade Structure
 - 4.7.1.1. Evaluate tariffs, tax structures and barriers to trade
 - 4.7.1.2. Reduce restrictions on imports that hinder access to goods for small business and investors
 - 4.7.2. Trade Facilitation
 - 4.7.2.1. Open or maintain LOC mechanisms and trade credits to trade critical goods
 - 4.7.2.2. Set trade priorities and explore new trade opportunities
 - 4.7.2.3. Initiate dialogue between country economic team and international actors responsible for granting preferential trading status
- 4.8. Market Economy
 - 4.8.1. Private Sector Development
 - 4.8.1.1. Assess the depth of the private sector, including weakness of the goods and service sector and its distribution channels
 - 4.8.1.2. Identify obstacles to private sector development (i.e., barriers to entry, high import taxes, import restrictions, lack of business credit, lack of power, telecommunications or transport, non-repatriation of profits)
 - 4.8.1.3. Take immediate steps to remove or counter these obstacles where possible
 - 4.8.1.4. Jumpstart small-scale private sector entrepreneurs through grants and loans to micro-entrepreneurs and small and medium enterprises (SMEs)
 - 4.8.2. Small and Micro-enterprise Regime
 - 4.8.2.1. Identify constraints to small business development and take steps to remove them where possible in the short-term (i.e., lack of credit, onerous taxes)
 - 4.8.3. Privatization
 - 4.8.3.1. Assess impact of State Owned Enterprises (SOE) on fiscal balance to determine whether fiscal drain or resource loss from unproductive firms can be offset through some type of privatization
 - 4.8.4. Natural Resources and Environment
 - 4.8.4.1. Assess and secure access to valuable natural resources
 - 4.8.4.2. Initiate process for addressing and resolving resource ownership and access issues
 - 4.8.4.3. Conduct national environmental survey
- 4.9. Legal and Regulatory Reform
 - 4.9.1. Property Rights
 - 4.9.1.1. Evaluate existing laws pertaining to land rights, registration of the property, and collateralization of movable and immovable property
 - 4.9.1.2. Take immediate steps where needed to establish process to resolve property rights issues
 - 4.9.2. Business/Commercial Law
 - 4.9.2.1. Evaluate restrictions on trade, commerce, and open market operations
 - 4.9.2.2. Evaluate existing laws pertaining to commercial and business operations
 - 4.9.3. Labor
 - 4.9.3.1. Evaluate existing laws pertaining to labor rights
 - 4.9.4. Economic Legal Reform
 - 4.9.4.1. Review civil and commercial codes

[DoS 2005]

- 4.9.4.2. Determine relevance of enforcement mechanisms
- 4.9.4.3. Retract necessary sanctions restrictions
- 4.9.4.4. Evaluate legal framework
- 4.9.4.5. Evaluate contract obligations with international financial community
- 4.9.5. Competition Policy
 - 4.9.5.1. Assess market for obvious problems with legal and regulatory framework for free market environment
- 4.9.6. Public Utilities and Resources Regulation
 - 4.9.6.1. Assess policy, governance and regulatory framework to rebuild utilities, power, mining, and other key infrastructure and facilities
- 4.9.7. Economic Enforcement and Anti-Corruption
 - 4.9.7.1. Identify incentives to reduce corruption
 - 4.9.7.2. Assess threat/existence of corruption in political system
 - 4.9.7.3. Identify drivers of corruption
 - 4.9.7.4. Develop laws promoting anti-corruption, accountability and transparency within government and private sector
 - 4.9.7.5. Create mechanisms to curtail corruption, including special prosecutors, witness and judge protection, and ethics norms
- 4.10. Agricultural Development
 - 4.10.1. Agricultural Land and Livestock
 - 4.10.1.1. Secure existing post-harvest storage facilities to prevent spoilage and looting of harvested crops
 - 4.10.1.2. Establish a process to determine land ownership, if disputed (e.g., if internally displaced person (IDP) claims to own land)
 - 4.10.1.3. Estimate crop production, mix, and input adequacy
 - 4.10.1.4. Assess current land distribution, and the degree of market integration
 - 4.10.1.5. Estimate farm income and poverty level
 - 4.10.1.6. Identify constraints to production
 - 4.10.1.7. Assess health, diversity, and number of animals
 - 4.10.1.8. Keep core reproductive group alive through water and/or fodder provision
 - 4.10.1.9. Destock if appropriate
 - 4.10.2. Agricultural Inputs
 - 4.10.2.1. Rebuild small scale irrigation systems and use technologies for collecting rainwater
 - 4.10.2.2. Identify critical points if emergency watershed protection is needed
 - 4.10.2.3. Determine agricultural needs within a watershed
 - 4.10.2.4. Locate significant sources of sediment
 - 4.10.2.5. Determine if land is a flood risk
 - 4.10.2.6. Identify agricultural time lines and necessary inputs according to the agricultural calendar
 - 4.10.2.7. Supply appropriate seeds, tools and other production inputs to farmers in affected region(s) (e.g., fertilizer, fuel, pesticide, equipment, etc.)
 - 4.10.3. Agricultural Policy and Financing
 - 4.10.3.1. Identify policy makers in the agricultural, natural resources and the environment areas and discuss their priorities for their respective sectors
 - 4.10.3.2. Identify existing Ministry officials in the country or who have fled and are willing to return to their home
 - 4.10.3.3. Rehabilitate physical structures
 - 4.10.3.4. Establish grant programs for all aspects of agricultural development
 - 4.10.3.5. Ensure equal access by minorities, women and poor
 - 4.10.4. Agricultural Distribution
 - 4.10.4.1. Channel food aid to promote market activities
- 4.11. Social Safety Net
 - 4.11.1. Pension System
 - 4.11.1.1. Assess existing pension systems for government, and parastatal employees
 - 4.11.1.2. Assess capability of government to pay pensions or reduce pension arrears if applicable
 - 4.11.2. Social Entitlement Funds

[DoS 2005]

- 4.11.2.1. Assess availability of social entitlement funds for disabled, widows, orphans and unemployed
- 4.11.3. Women's Issues
 - 4.11.3.1. VOID
- 4.12. Transportation
 - 4.12.1. Transportation Sector Policy and Administration
 - 4.12.1.1. Assess overall condition of national transportation infrastructure
 - 4.12.1.2. Determine and prioritize essential infrastructure programs and projects that reflect a balance of security, stabilization, and economic reconstruction
 - 4.12.1.3. Establish policies to support transportation priorities
 - 4.12.2. Airports Infrastructure
 - 4.12.2.1. Assess condition of existing airport facilities
 - 4.12.2.2. Construct expedient repairs or build new facilities to support security and stabilization and to facilitate re-establishment of commerce
 - 4.12.3. Roads Infrastructure
 - 4.12.3.1. Assess condition of existing roads and bridge facilities
 - 4.12.3.2. Construct expedient repairs or build new facilities to support security and stabilization and to facilitate re-establishment of commerce
 - 4.12.4. Railway Infrastructure
 - 4.12.4.1. Assess condition of existing railway facilities
 - 4.12.4.2. Construct expedient repairs or build new facilities to support security and stabilization and to facilitate re-establishment of commerce
 - 4.12.5. Ports and Waterway Infrastructure
 - 4.12.5.1. Assess condition of existing coastal and inland ports, harbors, and waterways facilities
 - 4.12.5.2. Construct expedient repairs or build new facilities to support security and stabilization and to facilitate re-establishment of commerce
- 4.13. Telecommunications
 - 4.13.1. Telecommunications Policy and Administration
 - 4.13.1.1. Assess overall condition of national telecommunications infrastructure
 - 4.13.1.2. Determine and prioritize essential infrastructure programs and projects that reflect a balance of security, stabilization, and economic reconstruction
 - 4.13.1.3. Establish policies to support telecommunications priorities
 - 4.13.2. Telecommunication Infrastructure
 - 4.13.2.1. Assess condition of existing telecommunications facilities
- 4.14. Energy
 - 4.14.1. Fossil Fuels Production and Distribution
 - 4.14.1.1. Assess overall condition of national energy infrastructure
 - 4.14.1.2. Determine and prioritize essential infrastructure programs and projects that reflect a balance of security, stabilization, and economic reconstruction
 - 4.14.1.3. Establish policies to support energy priorities
 - 4.14.2. Electrical Power Sector
 - 4.14.2.1. Assess condition of existing power generation and distribution facilities
 - 4.14.3. Energy Infrastructure
 - 4.14.3.1. Assess condition of existing natural resources conversion and distribution facilities, and power generation and distribution facilities
- 4.15. General Infrastructure
 - 4.15.1. Engineering and Construction
 - 4.15.1.1. Assess condition of existing facilities that are integral for effectively implementing other post-conflict sector essential tasks (e.g., fire and police stations, border checkpoints, IDP camps and shelters)
 - 4.15.2. Municipal Services
 - 4.15.2.1. Assess condition of existing local, municipal facilities that provide essential services to local population.
 - 4.15.2.2. Construct expedient repairs or new facilities to support restoration of stability and normalcy to local populations (e.g., schools, medical clinics, municipal buildings)

[DoS 2005]

4.16. Public Information and Communications

4.16.1. Disseminate Economic Stabilization and Infrastructure Information

4.16.1.1. Identify or establish outlets for international, national, and local news media

4.16.1.2. Utilize media as public information tool to provide factual information and control rumors

4.16.1.3. Issue effective press releases and timely provision of information services as needed in local languages

4.16.1.4. Assist National Transitional Administration and/or National Government to inform public regularly

[DoS 2005]

A.5 Justice and Reconciliation

The third portion includes tasks relating to developing mechanisms for addressing past and ongoing grievances [DoS 2005:V-1].

5. JUSTICE AND RECONCILIATION

5.1. Interim Criminal Justice System

- 5.1.1. Interim International Criminal Justice Personnel—Judges
 - 5.1.1.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.2. Interim International Criminal Justice Personnel—Prosecutors
 - 5.1.2.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.3. Interim International Criminal Justice Personnel—Defense Advocates
 - 5.1.3.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.4. Interim International Criminal Justice Personnel—Court Administrators
 - 5.1.4.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.5. Interim International Criminal Justice Personnel—Corrections Staffs
 - 5.1.5.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.6. Interim International Criminal Justice Personnel—Police/Investigators
 - 5.1.6.1. Deploy interim justice personnel to supplement indigenous criminal justice system
- 5.1.7. Interim International Legal Code
 - 5.1.7.1. Enact interim legal codes and procedures permitted by international law
- 5.1.8. Organized Crime
 - 5.1.8.1. Assess indigenous capacity to combat organized crime
 - 5.1.8.2. Establish multidisciplinary approach to address organized crime involving international intelligence, law enforcement and criminal justice personnel
- 5.1.9. Law Enforcement Operations
 - 5.1.9.1. Identify, secure and preserve evidence of war crimes, crimes against humanity, corruption, and transnational crimes, including terrorism, organized crime, financial crimes, trafficking in humans and narcotics
 - 5.1.9.2. Identify and detain perpetrators of these offences

5.2. Indigenous Police

- 5.2.1. Indigenous Police Personnel
 - 5.2.1.1. Vet and reconfigure existing police forces
 - 5.2.1.2. Train existing indigenous police in international policing standards
 - 5.2.1.3. Deploy police monitors/ mentors/trainers
- 5.2.2. Essential Police Facilities
 - 5.2.2.1. Inventory police stations, police mobility capabilities, police communications systems, data management systems and police headquarters
- 5.2.3. Accountability /Oversight
 - 5.2.3.1. Assess requirements to eradicate corruption in law enforcement community
 - 5.2.3.2. Reinforce oversight mechanisms

5.3. Judicial Personnel and Infrastructure

- 5.3.1. Vetting and Recruitment
 - 5.3.1.1. Inventory indigenous legal professionals
 - 5.3.1.2. Identify actual and potential leaders to incorporate into restructuring process
 - 5.3.1.3. Establish vetting criteria
- 5.3.2. Training/Mentoring
 - 5.3.2.1. Educate criminal justice personnel on interim legal codes
- 5.3.3. Judicial Support Facilities
 - 5.3.3.1. Inventory courts, law schools, legal libraries, and bar associations
- 5.3.4. Citizen Access
 - 5.3.4.1. Establish liaison mechanism between civilians and judicial authorities on legal matters
 - 5.3.4.2. Media campaigns to make citizens aware of rights, responsibilities and interim procedures and codes

5.4. Property

- 5.4.1. Prevent Property Conflicts
 - 5.4.1.1. Implement mechanisms to prevent unauthorized seizures of land/property
 - 5.4.1.2. Publicize dispute resolution options/alternative to violence
 - 5.4.1.3. Ensure coordination with law enforcement components to deter violence

[DoS 2005]

- 5.5. Legal System Reform
 - 5.5.1. Legal System Reorganization
 - 5.5.1.1. Develop strategy to rebuild criminal justice system
 - 5.5.1.2. Identify countries that can serve as models and sources of expertise
 - 5.5.2. Code and Statutory Reform
 - 5.5.2.1. Review current laws and resolve questions of applicability
 - 5.5.2.2. Abolish provisions incompatible with international standards of human rights
 - 5.5.3. Participation
 - 5.5.3.1. Create and strengthen legal aid and NGO groups
 - 5.5.3.2. Channel citizen input into law-drafting process
 - 5.5.3.3. Translate interim and important laws into local languages
 - 5.5.4. Institutional Reform
 - 5.5.4.1. Assess court administration capability and resources
- 5.6. Human Rights
 - 5.6.1. Abuse Prevention
 - 5.6.1.1. Monitor vulnerable groups and act preemptively to deter human rights abuses; implement effective warning mechanisms
 - 5.6.2. Capacity Building
 - 5.6.2.1. Assess capacity of indigenous communities, human rights and other groups; engage local communities, consult leaders
 - 5.6.3. Monitoring
 - 5.6.3.1. Establish international monitoring presence
 - 5.6.3.2. Develop indigenous human rights monitoring capacity
- 5.7. Corrections
 - 5.7.1. Incarceration and Parole
 - 5.7.1.1. Vet corrections personnel
 - 5.7.1.2. Determine status of prisoners held (political prisoners and war prisoners)
 - 5.7.1.3. Coordinate jurisdiction and handover with military as necessary
 - 5.7.2. Corrections Facilities
 - 5.7.2.1. Refurbish prison facilities at key sites
 - 5.7.2.2. Provide emergency lock-up facilities
 - 5.7.2.3. Coordinate jurisdiction and handover
 - 5.7.3. Training
 - 5.7.3.1. VOID
- 5.8. War Crime Courts and Tribunals
 - 5.8.1. Establishment of Courts and Tribunals
 - 5.8.1.1. Acquire secure facilities
 - 5.8.1.2. Establish jurisdiction, composition and mandate of local and international courts and tribunals
 - 5.8.1.3. Determine ratio of international to local judges and prosecutors
 - 5.8.2. Investigation and Arrest
 - 5.8.2.1. Set up an atrocity reporting system; refugee interviews
 - 5.8.2.2. Document and preserve evidence of mass atrocities and maintain data on sites
 - 5.8.2.3. Coordinate efforts with UN, regional organization and NGOs
 - 5.8.3. Citizen Outreach
 - 5.8.3.1. Publicize progress and work
 - 5.8.3.2. Publish indictments and statements
- 5.9. Truth Commissions and Remembrance
 - 5.9.1. Truth Commission Organization
 - 5.9.1.1. Solicit voluntary contributions from international donors
 - 5.9.1.2. Hire indigenous and international staff to set up commission
 - 5.9.1.3. Create indigenous dialogue on structure and mandate of commission
 - 5.9.1.4. Involve diverse groups in establishment of court
 - 5.9.2. Reparations
 - 5.9.2.1. Identify classes of eligibility

[DoS 2005]

- 5.9.3. Public Outreach
 - 5.9.3.1. Establish broad public information programs to promote efforts for reconciliation
 - 5.9.3.2. Develop public access to information
- 5.10. Community Rebuilding
 - 5.10.1. Ethnic and Intercommunity Confidence Building
 - 5.10.1.1. Identify mediators with dispute resolution skills to build trust and cooperation
 - 5.10.1.2. Enhance participation through public outreach
 - 5.10.1.3. Identify and incorporate credible local leadership and others with moral authority in the process
 - 5.10.1.4. Create coordinating mechanisms among international mission, local leaders, NGOs
 - 5.10.1.5. Implement media campaign promoting tolerance
 - 5.10.1.6. Insulate peace building efforts from spoilers.
 - 5.10.2. Religion and Customary Justice Practices
 - 5.10.2.1. Identify customary judicial practices, religious institutions and other leaders on local and national levels
 - 5.10.2.2. Identify role religious leaders play in reducing or promoting conflict
 - 5.10.2.3. Design community programs to support reconciliation based on religious and traditional practices
 - 5.10.2.4. Determine refugee, religious and legal requirements in case of birth, death or marriage
 - 5.10.3. Assistance to Victims and Remembrance
 - 5.10.3.1. Provide localized counseling to victims
 - 5.10.3.2. Establish missing persons initiatives
 - 5.10.3.3. Solicit funds and technical experts for identifying bodies and running missing persons programs
 - 5.10.4. Women
 - 5.10.4.1. Assess traditional role of women in society and their potential to contribute to reconciliation process
 - 5.10.4.2. Implement rape prevention and medical treatment procedures
 - 5.10.5. Vulnerable Populations
 - 5.10.5.1. Assess needs of vulnerable populations (e.g., war-wounded, internally displaced persons (IDPs), refugees, raped, tortured, disabled, orphaned youth, minority interests)
 - 5.10.6. Evaluating and Learning
 - 5.10.6.1. VOID
- 5.11. Public Information and Communications
 - 5.11.1. Disseminate Justice and Reconciliation Information
 - 5.11.1.1. Identify or establish outlets for international, national, and local news media
 - 5.11.1.2. Utilize media as public information tool to provide factual information and control rumors
 - 5.11.1.3. Issue effective press releases & timely provision of information services as needed in local languages
 - 5.11.1.4. Assist National Transitional Administration and/or National Government to inform public regularly

[DoS 2005]

Appendix B. Problem Formulation in LINGO®

The LINGO® 11.0 formulation of the problem is shown here.

B.1 Main.lg4

```
MODEL:
SETS:
MODES /1..3/;
TASKS /1..14/;
TIMES /1..52/;
DURATIONS ( TASKS,MODES ): D;
VARIABLE (TASKS, MODES, TIMES ): X;
STARTSTART ( TASKS, TASKS ) : ESS, SSLag;
STARTFINISH ( TASKS, TASKS ) : ESF, SFLag;
FINISHSTART ( TASKS, TASKS ) : EFS, FSLag;
FINISHFINISH ( TASKS, TASKS ) : EFF, FFLag;
EARLIES ( TASKS ): ES;
LATES ( TASKS ): LS;
DEMANDS1( TASKS, MODES ): DEM1;
DEMANDS2( TASKS, MODES ): DEM2;
DEMANDS3( TASKS, MODES ): DEM3;
ECONOMICS( TASKS, MODES): EE;
INCOMES( TASKS, MODES): MU;
ENDSETS
DATA:
D = @FILE( 'DURATIONS.TXT' );
```



```

F = 6;
BigN = 14;
! Resource Availabilities;
AMT1 = 2;
AMT2 = 50;
AMT3 = 2000;
! Demands for Resource 1;
DEM1 = @FILE( 'DEMAND1.TXT' );
! Demands for Resource 2;
DEM2 = @FILE( 'DEMAND2.TXT' );
! Demands for Resource 3;
DEM3 = @FILE( 'DEMAND3.TXT' );
! Start Start Precedence Matrix and Lags;
ESS = @FILE( 'SS.TXT' );
SSLag = @FILE( 'SS.TXT' );
! Start Finish Precedence Matrix and Lags;
ESF = @FILE( 'SF.TXT' );
SFLag = @FILE( 'SF.TXT' );
! Finish Start Precedence Matrix and Lags;
EFS = @FILE( 'FS.TXT' );
FSLag = @FILE( 'FS.TXT' );
! Finish Finish Precedence Matrix and Lags;
EFF = @FILE( 'FF.TXT' );
FFLag = @FILE( 'FF.TXT' );
! Early and Late Start Times;
! ES = @FILE( 'ESLS.TXT' );
! LS = @FILE( 'ESLS.TXT' );
EE = @FILE( 'EE.TXT' );

```

```

MU = @FILE( 'MU.TXT' );
ENDDATA

! -----BEGIN OBJS-----;

! Traditional Objective --- Min Makespan;
! [OBJECTIVE] MIN = @SUM ( VARIABLE( I, J, K ): K * X( BigN, J, K ) ) / 11 ;

! Services Objective;
! [OBJECTIVE] MIN = ( DELWATERPLUS + DELPOWERPLUS ) / 11;

! Employment Objective;
! [OBJECTIVE] MIN = DELECONMINUS;

! Income Objective;
! [OBJECTIVE] MIN = DELINCMINUS;

! -----BEGIN GOALS-----;

! First Goal;
!@SUM( VARIABLE( I, J, K ): K * X( 9, J, K ) )
- DELPOWERPLUS + DELPOWERMINUS = 24*11;
!@SUM( VARIABLE( I, J, K ): K * X( 10, J, K ) )
- DELWATERPLUS + DELWATERMINUS = 24*11;

! Second Goal;
!(1/500)*@SUM( VARIABLE( I, J, K ): EE( I, J ) * X( I, J, K ) )
- DELECONPLUS + DELECONMINUS = 0.30;

```

```

! Third Goal;
!(1/7)*@SUM( VARIABLE( I, J, K ): MU(I,J) * X(I,J,K) )
- DELINCPLUS + DELINCMINUS = 1.1;

! -----BEGIN CONSTRAINTS-----;

! There can be only one ... I am immortal, I have inside me blood of kings;
@FOR ( TASKS( I ): [ONEMODE]
    @SUM( VARIABLE( I, J, K ) : X( I, J, K ) ) = 1 );

! Start Start Precedence Constraints;
@FOR ( TASKS( M ):
    @FOR ( TASKS( N ): [SSPrecedence]
        @SUM ( VARIABLE( I, J, K ):
            ESS( M, N ) * ( (K + SSLag( M,N ) ) * X( M, J, K )
            - K * X( N, J, K ) ) ) <= 0 ) );

! Start Finish Precedence Constraints;
@FOR ( TASKS( M ):
    @FOR ( TASKS( N ): [SFPrecedence]
        @SUM ( VARIABLE( I, J, K ):
            ESF( M, N ) * ( (K + SFLag( M,N ) ) * X( M, J, K )
            - (K + D(N,J) ) * X( N, J, K ) ) ) <= 0 ) );

! Finish Start Precedence Constraints;
@FOR ( TASKS( M ):
    @FOR ( TASKS( N ): [FSPrecedence]

```

```

@SUM ( VARIABLE( I, J, K ):
    EFS( M, N ) * ( ( K + D(M,J) + FSLag( M,N ) ) * X( M, J, K )
    - K * X( N, J, K ) ) ) <= 0 ) );

! Finish Finish Precedence Constraints;
@FOR ( TASKS( M ):
    @FOR ( TASKS( N ): [FFPrecedence]
        @SUM ( VARIABLE( I, J, K ):
            EFF( M, N ) * ( ( K + D(M,J) + FFLag( M,N ) ) * X( M, J, K )
            - ( K + D(N,J) ) * X( N, J, K ) ) ) <= 0 ) );

! Resource 1 Constriants;
@FOR( TIMES( K ): [Resource1Const]
    @SUM( TASKS( M ):
        @SUM( MODES( N ):
            DEM1(M,N) * @SUM( TIMES( S ) |
                S #GE# ( K - D(M,N) ) #AND# S #LE# ( K - 1 ) : X( M,N,S ) )
            )
        ) <= AMT1
    );

! Resource 2 Constraints;
@FOR( TIMES( K ): [Resource2Const]
    @SUM( TASKS( M ):
        @SUM( MODES( N ):
            DEM2(M,N) * @SUM( TIMES( S ) |
                S #GE# ( K - D(M,N) ) #AND# S #LE# ( K - 1 ) : X( M,N,S ) )
            )
        )
    );

```

```

) <= AMT2
);

! Resource 3 Constraints;
@FOR( TIMES( K ): [Resource3Const]
    @SUM( TASKS( M ):
        @SUM( MODES( N ):
            DEM3(M,N) * @SUM( TIMES( S ) |
                S #GE# ( K - D(M,N) ) #AND# S #LE# ( K - 1 ) : X( M,N,S ) )
            )
        ) <= AMT3
    );

!Dummy End Time Constraint;
[FINALTIME] @SUM ( VARIABLE( I, J, K ):
    K * X( BigN, J, K ) ) <= 52*11;

!All variables binary;
@FOR ( VARIABLE ( I, J, K ): @BIN ( X ) ) ;

```

B.2 Early Late Starts.lg4

```

model:

sets:
MODES /1..3/;
TASKS /1..14/;
TIMES /1..52/;

```

```

DURATIONS ( TASKS, MODES ): D;
VARIABLES ( TASKS ): START, FINISH;
VAR2S ( TASKS, MODES ): Y;
STARTSTART ( TASKS, TASKS ) : ESS, SS;
STARTFINISH ( TASKS, TASKS ) : ESF, SF;
FINISHSTART ( TASKS, TASKS ) : EFS, FS;
FINISHFINISH ( TASKS, TASKS ) : EFF, FF;
endsets

data:
D = @FILE( 'DURATIONS.TXT' );
BigN = 14;
! Start Start Precedence Matrix and Lags;
ESS = @FILE( 'SS.TXT' );
SS = @FILE( 'SS.TXT' );
! Start Finish Precedence Matrix and Lags;
ESF = @FILE( 'SF.TXT' );
SF = @FILE( 'SF.TXT' );
! Finish Start Precedence Matrix and Lags;
EFS = @FILE( 'FS.TXT' );
FS = @FILE( 'FS.TXT' );
! Finish Finish Precedence Matrix and Lags;
EFF = @FILE( 'FF.TXT' );
FF = @FILE( 'FF.TXT' );
enddata

! Change this to max for late starts;;
[objective] min = @sum( VARIABLES( i ): START(i) );

```

```

! Enforece Max Time;
@for( tasks( i ) : finish( i ) <= 52 );

! Start Start Constraints;
@FOR( TASKS( i ):
    @FOR( TASKS( j ): [SSPrecedence]
        ESS(i,j) * ( start(i) + SS(i,j) - start(j) ) <= 0
    )
);

! Start Finish Constraints;
@FOR( TASKS( i ):
    @FOR( TASKS( j ): [SFPrecedence]
        ESF( i,j ) * ( start(i) + SF(i,j) - finish(j) ) <= 0
    )
);

! Finish Start Constraints;
@FOR( TASKS( i ):
    @FOR( TASKS( j ): [FSPrecedence]
        EFS( i,j) * ( finish(i) + FS(i,j) - start(j) ) <= 0
    )
);

! Finish Finish Constraints;
@FOR( TASKS( i ):
    @FOR( TASKS( j ): [FFPrecedence]

```

```

    EFF( i,j ) * ( finish(i) + FF(i,j) - finish(j) ) <= 0
  )
);

! One mode per activity;
@FOR( TASKS( i ): [ONEMODE]
    @SUM( VAR2S( i,j ):
        Y(i,j)
    ) = 1
);

! Starts, Finishes, and Modes must agree;
@FOR( TASKS( i ): [SFMAGREE]
    start( i ) + @SUM( MODES( j ): D(i,j) * Y(i,j) ) - finish(i) = 0
);

! Binary vars;
@FOR( VAR2S( i,j ): @BIN( Y( i,j) ) );

end

```

B.3 Data Files for Example Problem

Durations.txt

```

0 100 100
30 40 50
7 7 14
3 6 9

```


12 24 40

13 20 25

1 2 3

1 2 3

40 45 50

3 6 12

5 7 9

0 100 100

0 100 100

0 100 100

Demand1.txt

0 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

1 0 0

0 0 0

0 0 0

0 0 0

Demand2.txt

0 0 0

0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 2 10
0 0 0
0 0 0
0 0 0

Demand3.txt

0 0 0
0 10 275
0 5 137
0 1 25
0 8 180
0 5 112
0 1 27
0 1 25
0 8 200
0 2 60
0 2 50
0 0 0
0 0 0
0 0 0

SS.txt

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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SF.txt

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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FS.txt

0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 1 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
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FF.txt

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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

EE.txt

0 100 100
0 12 285
0 7 147
0 3 35
0 10 190
0 7 122
0 3 37
0 3 35
0 10 210
0 4 70
0 4 60
0 100 100
0 100 100
0 100 100

MU.txt

0 100 100
0 1 1
0 0.9 1

0 1 1.2
0 1.2 1.1
0 0.8 0.8
0 1.2 0.9
0 0.8 0.8
0 1 1.1
0 0.8 0.8
0 0.9 1.2
0 100 100
0 100 100
0 100 100

Appendix C. Air Force Blue Dart

Blue Dart — 703 Words

To truly achieve victory as Clausewitz defined it - to attain a political objective - the United States needs a military whose ability to kick down the door is matched by its ability to clean up the mess and even rebuild the house afterward.

— Robert M. Gates, Secretary of Defense, 2009

Since the decline of the Cold War, the risk of major conflict between powerful industrialized nations has significantly decreased. Insecurity in the twenty-first century is forecast to arise from the debris of imploding states. Such situations may require intervention — using military, diplomatic, or humanitarian means — by concerned states, and the frequency with which these interventions occur is increasing. To meet this new operational challenge, the US government is adapting its operational planning procedures to account for Security, Stabilization, Transition, and Reconstruction Operations.

The Special Inspector General for Iraq Reconstruction’s (SIGIR) recently released report, *Hard Lessons: The Iraq Reconstruction Experience*, is strongly critical of the planning for post-conflict Iraq. SIGIR reports that the planning process “had been fragmented from its beginning” and calls for “more integrated planning and a capacity to address worst-case scenarios were subordinated to the views of . . . officials who were committed to a rapid transfer of power” (p. 16). In late summer of 2003, the White House had to shift its position to request \$20 billion of supplemental funding for reconstruction. This prompted some in Congress to express dismay at the administration’s lack of planning and unrealistic cost estimates. Funding for Iraq reconstruction has since exceeded \$50 billion.

While recent Department of Defense publications such as the new Joint Publication 1 and the Army’s new Field Manual 3-07 have changed to acknowledge the

importance of the full spectrum of conflict — to include stabilization operations — the United States Government in general and the Department of Defense specifically must institutionalize the ability to create integrated, interagency plans for post-conflict reconstruction.

The United States Institute for Peace, the State Department’s Office of the Coordinator Reconstruction and Stabilization, studies by the RAND corporation, and studies by the former UN peacekeepers all agree that revitalizing the legitimate economy of a post-conflict state is of primary importance — second perhaps only to enforcing stable security — and that reconstructing critical infrastructure is a key enabler for any economy. The current body of literature is consistent in acknowledging the positive relation between employment and social welfare, and S/CRS recommends designing “initiatives to provide immediate employment” and creating “opportunities for young males” via public works jobs in its initial response tasks. The newly released United States Government Interagency Counterinsurgency Initiative’s U.S. Government Counterinsurgency Guide affirms the importance of economic considerations in stabilization operations: stating that COIN operations seek

. . . to provide essential services and stimulate long term economic growth, thereby generating confidence in the government while at the same time reducing the pool of frustrated, unemployed young men and women from which insurgents can readily recruit (p. 3).

Creating the links between government departments, OGAs, and NGOs will take time and is a question of bureaucracy and public policy, but the use of tested and sound management tools can begin immediately within each agency. The public and private sectors abound with established tools for managing large-scale complex projects like reconstruction.

Researchers in AFIT’s Future Operations Investigation Lab have developed a proof-of-concept project scheduling framework for post-conflict reconstruction that schedules reconstruction activities to capture stakeholder’s preferences. Project

scheduling combined with goal programming allows the model to capture requirements beyond what is captured by traditional project scheduling.

No amount of planning will replace competent commanders on the ground: as General Field Marshall Helmuth von Moltke famously remarked, “. . . no plan of operations extends with any certainty beyond the first contact with the main hostile force.” However, a project schedule forms a baseline by which any SSTRO can be planned for and measured against. Using sound analytical processes, different SSTRO strategies can be compared. Sensitivity analysis can be conducted to explore the effect of different parameters on the schedule of reconstruction activities.

The use of established project management techniques allows the use of established project management tracking tools. To wit, using sound management practices adds quantitative defensibility to an SSTRO plan and can uncover shortfalls or other problems.

The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the US Government.

Vita

Capt. Andrew D. Chaney graduated *magna cum laude* from the University of Louisiana at Lafayette with a Bachelor of Science in Mechanical Engineering in May of 2004. He received a commission from the Air Force Officer Training School on the 24th of September of that same year. His first assignment was to the Air Force Research Laboratory's Propulsion Directorate at Wright Patterson Air Force Base. In August of 2007, he entered the Graduate School of Engineering and Management at the Air Force Institute of Technology. Following graduation from AFIT, he has received an assignment to the 17th Test Squadron, Schriever AFB, CO.

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