Application of Systems Engineering (SE) Concepts as Enhancements to Project Lifecycle Methodologies

Presentation to <Forum>
<Venue> @ <Town>, <Country>
<Date: dd mmm yyyy>

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Introduction:

- The world needs more infrastructure than any governments can deliver. Long-term projections call for an estimated **US$ 57 trillion globally to build new and refurbished existing infrastructure** between 2013 and 2030;
- Infrastructure expenditure in **Sub-Saharan Africa** was expected to **increase by 10%** on a year-to-year basis from **US$ 70 billion in 2013 to US$ 180 billion by 2025**, RSA and Nigeria accounting for the bulk of this expenditure;
- **South Africa’s investment in infrastructure has grown** relatively consistently from an estimated **US$ 7 billion in 2001 to US$ 22 billion by 2012**. Besides, **power generation** could be the key priority for infrastructure investment, **followed by road and rail transportation** (likely to grow to just short of US$ 9 billion by 2015) and **sanitation services**. [“water crisis” not factored in yet ...]

“Investments in modern infrastructure lay the foundations for economic development and growth. Building roads, bridges, power transmission lines and making other improvements create jobs. When completed, these projects help a society increase its wealth and its citizens' standard of living.” — US DoS, 2012
FACT – Large Infrastructure Projects are *increasingly* suffering from:

(1) Schedule Overruns (i.e. up to 24 months, if not more);

Almost half of organisations surveyed had experienced “more than 6 months” delays over the last 12 months – failure looms!

(2) Costs Overruns (i.e. up to 350% in *annualised* terms, according to IPA);

A cost overrun of 25% in *annualised* terms entails “project failure” ...

(3) Long commissioning time (e.g., delayed/substandard ramp-up caused up to 30% “loss of production” in the first 2 to 3 years of operations);

(4) Failure to meet the requirements or satisfy the needs of the client(s).

“The megaproject market is worth about $9-trillion each year, and globally big builds are in a mess. It is rare to have one completed on time and on budget.” – Nevin, 2015
Introduction:

The PWC “Trends, challenges and future outlook – *Capital projects and infrastructure in East Africa, Southern Africa and West Africa*” (Nov. 2014), blames Budget Overruns on Poor Project Management:

[1]“Inadequate Project Management” & [4] “Change of requirements” are highest-ranked items within the project managers’ control – Yet, they seem unable to fix the situation!
The Real Problem:

Due to the “increased complexity” in Large Infrastructure Projects (LIPs), traditional approaches are no longer adequate for successful delivery; “… the complexity of construction can no longer be ignored and that the basis for our PM paradigms should thus be redefined!” – Bertelsen, 2003

“Building physical stuff {e.g., highway, port} is easy, producing improved services {e.g., transportation system} much more difficult.” – Andrews, 2012

LIPs are “Technological” systems nested in “Socio-Economic” systems!

The New Approach: **PROJECT MANAGEMENT + SYSTEMS ENGINEERING**

is needed to ensure large, complex projects are delivered on time, on budget, and meet the owner’s (business or operational) requirements ...

INCOSE: “Systems Engineering (SE) is an interdisciplinary approach and means to enable the realisation of successful systems – It focuses on defining customer needs and required functionality early in the development cycle …”
Project Complexity:

When is a (large infrastructure) project deemed “complex”?

- The **complexity of a system** is usually determined by the **number of parts or activities**, the **degree of differentiation** between the parts, and the **structure and strength of their connections** ... Furthermore, complex systems have multiple interacting components whose **collective behavior cannot be simply inferred from the behavior of the individual components** – S.J. Gould, 1996;

- A project is more or less complex in relation to the number of activities, the type and strength of relationships to other project activities, and the degree and type of relationships to the project environment;

  “A project can be said to be complex if it consists of many interdependent parts, each of which can change in ways that are not totally predictable, and which can then have unpredictable impacts on other elements that are themselves capable of change.” – Dr. Terry Cooke-Davies, founder of Human Systems Int’l.

Delivery of Large Infrastructure Project should, thus, consider the **relationships** among activities, between activities and the project environment – Notions of systems, multiple causality, connectivity, emergence and lifecycle shall apply ...
Reasons for Project Failure:

❖ At the Micro Level (as often experienced by Project Team members):

Main Reasons for Project Failure

- Lack of User Input
- Incomplete Requirements
- Changing Requirements
- Lack of Executive Support
- Technology Incompetence
- Lack of Resources
- Unrealistic Expectations
- Unclear Objectives
- Unrealistic Timeframes
- New Technology

Issues related to Requirements

 Adapted from: The Chaos Report [Standish Group, 1994 & beyond ...]

Up to half of “reasons for failure” has to do with issues related to requirements ...

“If you fail to manage requirements, your project will fail to meet requirements”
Reasons for Project Failure:

- At the Macro Level (as often experienced by company executives):

No company project framework
- No discipline in following any framework or process
- Lack of effective & open resource management
- Inadequate information for decision making
- Too many projects are started
- Resources are overstretched

No clear strategy
- Inadequate prioritisation & decision making criteria
- Functions have incompatible projects frameworks & processes
- Functions may reverse previously made decisions

Poor/Bad Corporate Leadership, Policies, and/or Governance
- Short-term focus
- No link between strategy & business plans
- Decisions not aligned to strategy
- Projects not aligned to strategy and to each other

Projects fail, are terminated, late, or never started!

Adapted from: *Reaping the Rewards from all your Business Projects*, R. Buttrick, 2005
Approaches to Project Success:

- **Requirements Management** is the key “space” where Project Management (PM) meets Systems Engineering (SE).

PMBOK states: Project Management is “…the application of knowledge, skills, tools, and techniques to project activities in order to meet project requirements” – which evidently falls in the realm of Systems Engineering ...

Project requirements end only when the users/stakeholders have been satisfied! SE treats the requirements of the complete lifecycle as core elements; so a specific step is built-in at each phase to clearly review whether the requirements were met.
Approaches to Project Success:

Project is a **system**; if ORS or “element” changes, so does the project – **Congruency**!

The Project Manager will rely on SE Plan (SEMP) in managing the various “linkages” between and among diverse domains (Dj) of this project system ...
Approaches to Project Success:

A more comprehensive **Project Lifecycle Model** – which indeed includes the *operational environment*, thus aligns to Systems Engineering – is shown here:

The SE-based Project Lifecycle Model entails the following:

- Operational matters shall be considered *first* during Concept & Development; [In accordance with “9 Laws of Effective SE” by Zane Scott: Law #1 – *Begin with the End in Mind*]
- Focus should shift away from “building the physical facility” to developing a “successful system” that effectively improves the *Operational Environment*;
- Project Team’s active involvement may end at Close-Out; however, the team should be “intermittently” involved in *Operational Environment* (e.g., at PIR) to allow for Lessons-Learned, fine-tuning of Design, and/or Retrofitting ...

_FEL_ = Front End Loading  
System Lifecycle Stage as per ISO/IEC 15288
Approaches to Project Success:

The traditional focus on Execution Phase is incorrect, be it on basis of value or costs:

The “value” of a system (i.e. sum-total of benefits it might produce throughout its lifecycle) is “created” during its Study Stage (i.e. FEL-1 to FEL-3/4); thus, it is merely “delivered” during Execution!

Fixing error(s) during Operations, owing to interrelationships and/or interface matters, could prove as overwhelming as redesigning and rebuilding the system in its entirety ...

While only a minor portion of the Asset Lifecycle Cost is spent at Study Stage, any design/solution arising from FELs has already *determined* the bulk of costs. Therefore, skilled (Soft & Hard) SE resources must be assigned to Study Stage!
Various Project Lifecycle activities are executed along three essential “tracks” such as: (1) Business Stream, (2) Technical Stream and (3) Integration Stream.

Note:
In the early phases (i.e. Concept), more emphasis must be on “Business” aspects (e.g., commercial validation) than on “Technical” aspects (e.g., Engineering Design) ... and vice-versa as of FEL-3.
## Approaches to Project Success:

Typical project-related activities for Business, Technical and Integration tracks ...

<table>
<thead>
<tr>
<th>Track</th>
<th>Typical Project Lifecycle Activities</th>
<th>Skills Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business Track</strong></td>
<td>▪ Recognise opportunity&lt;br&gt;▪ Develop Business Requirements&lt;br&gt;▪ Justify “Market” Demand/Appetite&lt;br&gt;▪ Develop Business Case (i.e. ROI)</td>
<td>▪ Select acquisition approach&lt;br&gt;▪ In-progress ROI projections&lt;br&gt;▪ Take System into Business Plan&lt;br&gt;▪ Confirm ROI (during Operations)</td>
</tr>
<tr>
<td><strong>Technical Track</strong></td>
<td>▪ Collect Owner/User Requirements&lt;br&gt;▪ Develop Systems Requirements&lt;br&gt;▪ Develop System CONOPS&lt;br&gt;▪ Justify Technical Feasibility</td>
<td>▪ Manage Technical Specifications&lt;br&gt;▪ Direct ‘Design-to’/‘Build-to’ Specs&lt;br&gt;▪ Conduct System Integration&lt;br&gt;▪ Conduct Verification &amp; Validation</td>
</tr>
<tr>
<td><strong>Integration Track</strong></td>
<td>▪ Manage project stakeholders&lt;br&gt;▪ Confirm resource availability&lt;br&gt;▪ Predict costs and phasing&lt;br&gt;▪ Deploy available resources&lt;br&gt;▪ Manage costs &amp; schedule&lt;br&gt;▪ Select best-value supplier(s)</td>
<td>▪ Manage supplier(s) &amp; contract(s)&lt;br&gt;▪ Manage and motivate resources&lt;br&gt;▪ Manage project risk and value&lt;br&gt;▪ Manage Project Configuration&lt;br&gt;▪ Manage reviews and approvals&lt;br&gt;▪ Conduct Project Integration</td>
</tr>
</tbody>
</table>

Adapted from: *Visualising Project Management*, K. Forsberg et al., 2005
Approaches to Project Success:

Principles of an effective Gate Review:

- Gate Review Processes shall be acknowledged as a governance function and its custodianship to reside at same level as that at which the Portfolio Management function resides – its recommendations serve as input to CIC;
- Gate Review Panels to operate independently vis-à-vis project teams (as per the principle of segregation of duties) and shall consist of senior and mature professionals formally appointed thereto; and
- Gate Reviews to also include considerations of commercial, financial, legal, social, political, economic, operational, disposal aspects, etc., particularly so during the early phases (i.e. FEL-1 and FEL-2) also known as optioneering;

Typical decision at each event could be one of these mutually exclusive options:

- **Pass**
  - Acceptable
  - Proceed with Project

- **Pass “If”**
  - Acceptable with Reservations
  - Address Issues First!

- **On Hold**
  - Unacceptable
  - Do Not Proceed, Redo Project FEL

- **Stop**
  - Unsalvageable
  - Terminate the Project
Approaches to Project Success:

Approach to an effective Gate Review:

Backward-looking Review:
This seeks to establish to what extent the works of the particular “phase” (e.g., FEL, Programme Stage) were executed in *compliance* with relevant portions of applicable lifecycle and regulatory frameworks ...

Forward-looking Review:
This seeks to establish the degree of commercial and technical *viability* (as per the outcome of the works of the “phase”) and *readiness* to proceed, to support a Go/No Go and/or Investment decision regarding ensuing “phases” ...

<table>
<thead>
<tr>
<th>Gate Review Outcome</th>
<th>Pass</th>
<th>Pass “If”</th>
<th>Put on Hold</th>
<th>Stop / Terminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR/Backward Looking</td>
<td>✓</td>
<td>Minor Failure of either</td>
<td>Any other combinations</td>
<td>✓</td>
</tr>
<tr>
<td>GR/Forward Looking</td>
<td>✓</td>
<td></td>
<td></td>
<td>Major Failure</td>
</tr>
</tbody>
</table>
Approaches to Project Success:

The structural integration of the **Verification and Validation (V&V)** of design proposals is important in order to demonstrate the **adequacy** and **efficiency** of the proposed solution – thus, V&V shall be anchored into the design processes ...

The hierarchical breakdown (e.g., during Development) of the project’s System Architecture is Verified & Validated at System Integration (e.g., during Execution)!
Approaches to Project Success:

Risk Management starts early in the project, by identifying the full range of interacting threats and opportunities. Analysis selects the most critical ones to mitigate or to plan for. The process continues throughout the project (right up to Disposal) with the monitoring of “registered” threats/opportunities and a well-planned response to correct problems as they occur.

In this diagram, “Risk” shall include both “Threat” and “Opportunity”!
Approaches to Project Success:

Stakeholder Management – Input & Buy-in ...

- Right Syst Requirements, Business Case?
- Right ConOps, Design Option?
- Right Design, Execution Plan?
- Right Implementation?
- Right System Deployed?

Requirement Elicitation ... and Validation!

In Large Infrastructure Projects, Stakeholder Management (SM) should look beyond “just keeping project stakeholders informed ... and content with project works”.

A key purpose of Stakeholder Management is to secure input to complex projects as follows:
(1) Requirement Elicitation;
(2) In-Process Validation;
(3) System Validation.

Stakeholder Validation Role [Adapted: SE for Intelligent Transportation System, 2005]
## Key Operational Readiness Domains (to be addressed in Operational Readiness Plan)...

<table>
<thead>
<tr>
<th>Primary OR Domain</th>
<th>OR Domain’s Aspects</th>
<th>OR Domain Considerations [Few Pointers]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Resources</td>
<td>Training &amp; Skills Transfer</td>
<td>New skills required? For whom? Skill Provision Scheme?</td>
</tr>
<tr>
<td></td>
<td>Human Resources Capacity</td>
<td>New recruits required? By when?</td>
</tr>
<tr>
<td></td>
<td>Organisational Change Management</td>
<td>Any changes to Structure (and office space) or Culture?</td>
</tr>
<tr>
<td>Operational Support</td>
<td>Bulk Supply/Services &amp; Utilities</td>
<td>New, extra Water/Electricity Supply, Sewerage needed?</td>
</tr>
<tr>
<td></td>
<td>Supply Chain Management</td>
<td>Any feedstock, goods &amp; services needed? From whom?</td>
</tr>
<tr>
<td></td>
<td>Configuration Management</td>
<td>How to maintain current &amp; accurate versions of data?</td>
</tr>
<tr>
<td></td>
<td>Technology Integration</td>
<td>How to migrate existing systems to new technology?</td>
</tr>
<tr>
<td>System Utilisation</td>
<td>Operational Health &amp; Safety &amp; Security</td>
<td>What HSS regimen required for safe utilisation?</td>
</tr>
<tr>
<td></td>
<td>Operational Licencing &amp; Permitting</td>
<td>Any Operating Licence, Waste Disposal Permit needed?</td>
</tr>
<tr>
<td></td>
<td>SOMAR – ities</td>
<td>Any set-up to allow system operate in its environment?</td>
</tr>
<tr>
<td></td>
<td>Product Testing</td>
<td>What testing process, equipment and spares needed?</td>
</tr>
<tr>
<td>Facilities &amp; Tools</td>
<td>Operations Facilities</td>
<td>Any facilities, equipment needed for operations?</td>
</tr>
<tr>
<td></td>
<td>Spare Parts and/or Components</td>
<td>Any spares, feedstock needed to test, operate?</td>
</tr>
<tr>
<td></td>
<td>Maintenance Facilities and Equipment</td>
<td>Any facilities, equipment needed for maintenance?</td>
</tr>
<tr>
<td>Processes &amp; Procedures</td>
<td>Maintenance Regime &amp; Plans</td>
<td>What types/scope, budget and timing of maintenance?</td>
</tr>
<tr>
<td></td>
<td>Operational Risk Management</td>
<td>What operational risks to mitigate? Manuals needed?</td>
</tr>
<tr>
<td></td>
<td>Warrantees Management</td>
<td>What scope &amp; processes, whose responsibility?</td>
</tr>
</tbody>
</table>
Benefits of Applying SE:

Research work by Eric Honour (2013) has revealed that “There is an optimum amount of Systems Engineering for best success, representing an ‘investment’ of 14.4% of the total program {project} cost on Systems Engineering activities”.

Thus, a judicious application of SE principles, concepts, and practices on LIPs was confirmed to have reduced both (i) the Average Cost/Schedule Overruns (<10%), (ii) the Variances around such averages – besides meeting project requirements!

“One of the most important findings is that LIPs must be conceived, managed and operated as an integrated whole {i.e. SE principle}, focusing not only on the completion of a physical project as an end in itself, but also on stakeholders involved.” – NETLIPSE
E 6 Project Consulting (Pty) Ltd

Offering YOU the “Systems Thinking Approach” to Project Management!

“The significance of project complexity to project success or otherwise cannot be underestimated, hence the compelling need to allow for a thorough understanding of the inherent complexities in an infrastructure delivery system.” – Baccarini, 1996

For More Information:

- Visit our website at www.e6pc.com
- Contact our Advisory Services at consult@e6pc.com
- Attend our SE-PLM MasterClass containing the following modules:
  1. Project Lifecycle Management
  2. Stakeholder Management
  3. Requirement Management
  4. Engineering Management
  5. Risk Management
  6. Readiness Management
  7. Business Case Management
- Arrange for “In-House” Workshops on topics such as:
  1. Gate Review (GR) Process — Establish, Assess, Conduct;
  2. Earned Value Management for Large, Complex Projects ...