Multi-skilling and sustainability initiative of Assam Engineering College (AEC)

Proceedings of Professional Development Course on Capacity Building in Construction Management – *For the Department of Town & Country Planning, Assam through Assam Engineering College and in collaboration with The University of Melbourne, Australia*

17-24 January 2019

Editors:

Dr Hemanta Doloi
Prof Atul Bora

Assam Engineering College
Jalukbari, Guwahati, Assam

Schedule (Revised on 19 January 2019)

Training Program on “Construction Management”

(for Town & Country Planning, Assam)

Date: 17th January – 24th January 2019

Venue: Assam Engineering College

Jalukbari, Guwahati - 13

Date	**9:30am – 10:00am**	**Session 1 (10:00am-11:30am)**	**Session 2 (11:45am-1:15pm)**	**Session 3 (2:00pm-3:15pm)**	**Session 4 (3:30pm-4:45pm)**
17/01/2019	Sustainable Construction & Opening Remarks	Project Management - I	Project Management - I	Project Management - I	Project Management - I
18/01/2019		Construction Management - I	Construction Management - I	Construction Management - I	Construction Management - I
19/01/2019		Financial & Legal Management [Tendering, Bidding, Contract, Arbitration]	Financial & Legal Management [Tendering, Bidding, Contract, Arbitration]	Latest Software used in Construction Management	Latest Software used in Construction Management
20/01/2019	Sunday				
21/01/2019		Solid Waste management	Solid Waste management	Software used in Structural Design	Software used in Structural Design
22/01/2019		Drainage System Design	Drainage System Design	Water Supply Project	Traffic and Transportation Project
23/01/2019	Public Holiday				
24/01/2019	Cancelled but contents are adjusted on earlier days				

Tea Breaks
11:30am-11:45am
3:15pm-3:30pm

Lunch Breaks
1:15pm-2:00pm

Welcome, Overview and Road map - Dr Atul Bora

सत्यमेव जयते

WELCOME
ALL RESOURCE PERSONS & PARTICIPANTS
FOR
SHORT COURSE FOR CAPACITY BUILDING ON CONSTRUCTION MANAGEMENT
[FOR DEPARTMENT OF TOWN & COUNTRY PLANNING, ASSAM]
17-1-19 to 24-1-19

ASSAM ENGINEERING COLLEGE
GUWAHATI-13

1

Sustainable Construction: Roadmap for Assam Engineering College

A. Bora
Assam Engineering College

Bora, A. (2018) Sustainable Construction and Roadmap ahead

INSTITUTIONAL VISION

VISION

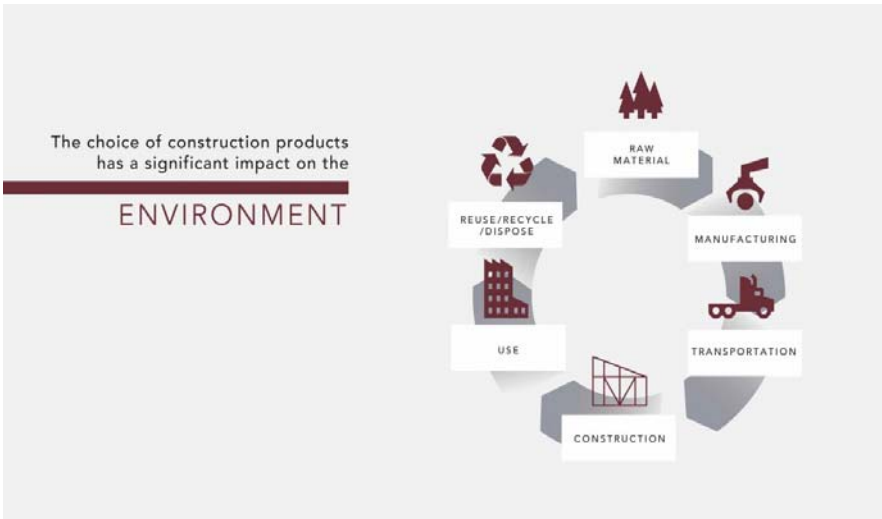
- **To be an institution for promoting and supporting sustainable development.**

MISSION

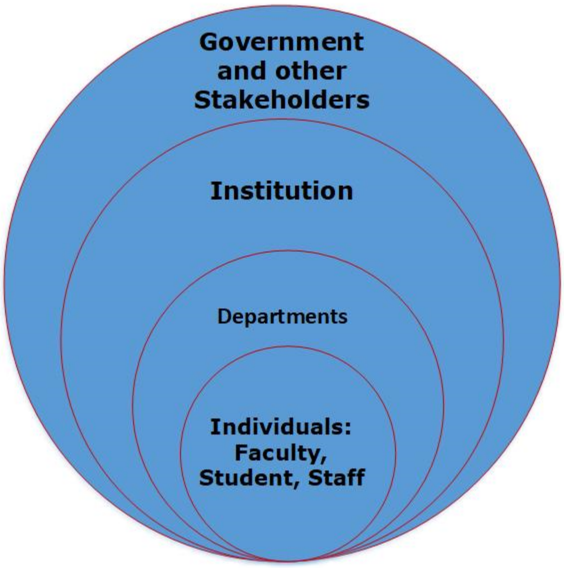
- **To prepare technical manpower with knowledge skills and values of sustainability.**
- **To take up relevant problems of society & industry as projects, research themes for study and to provide technological solutions**

Bora, A. (2018) Sustainable Construction and Roadmap ahead

Sustainable Construction?



Bora, A. (2018) Sustainable Construction and Roadmap ahead



Bora, A. (2018) Sustainable Construction and Roadmap ahead

Sustainable Construction

- Traditional construction engineering and management focuses on three parameters
  - Cost?
  - Quality?
  - Time?
    - Given the Resources?
- Needs to incorporate Sustainability Parameters?

References:

- **Bora, A (1997): <u>Sustainability Parameters and Role of Civil Engineers.</u> *Proc. of the International Conference on Civil Engineering of Sustainable Development, Department of Civil Engineering, University of Roorkee,* pp.807-818**

- **Bora, A. (2008): <u>The City Crisis: Breaking the Vicious Circle</u> *Proc. of the 7th International Ecocity Conference, Ecocity World Summit*, April 22-26, 2008, San Francisco, California, USA**

Bora, A. (2018) Sustainable Construction and Roadmap ahead

MULTI-SKILLING AND SUSTAINABILITY CENTRE

- TO IMPART SYSTEMIC & HOLISTIC THINKING SKILL
  - Needs Systems perspective and holistic thinking as regards construction and management of the built environment, taking a lifecycle perspective. Construction as the comprehensive cycle of activities
  - from material extraction and product manufacture to product transportation building design and construction, operations and maintenance, and building reuse or disposal.
- TO ADD VALUES, PERSPECTIVES AND ACCOUNTABILITY
- Needs to engage not only technical issues, but social, legal, economic, administrative and political matters as well

- TO IMPART LIFE-CYCLE-THINKING SKILL
  - TO MAKE THE ENGINEERS THINK HOW ENGINEERING DESIGN AND ACTIVITIES IMPACT PEOPLE AND NATURAL ENVIRONMENT.
  - CONSEQUENCES OF ENGINEERING DESIGN AND ACTIVITIES/DECISIONS ON CURRENT AND FUTURE GENERATIONS

- TO INTEGRATE SUSTAINABILITY IN ADDITION TO THE TRADITIONAL COST, QUALITY & TIME MANAGEMENT

Bora, A. (2018) Sustainable Construction and Roadmap ahead

Sustainability Parameters

- Need to integrate Sustainability Parameters at all stages of the project life cycle, particularly the early funding allocation, planning and conceptual design phases.

- Cost: from their complete life cycle perspective, including operations and maintenance, and also the end-of-service life decision, Environmental Costs

- Quality: Impact on Neighborhood and community, City, State, Nation and World, Disaster proneness of human settlements
  - Value-based decision making: Use of lens of sustainability
  - Stakeholders' engagement and collaborative interdisciplinary working
- Needs to consider the regional and global effects of building and development. Far from being merely a location for construction, each site consists of interconnected living systems, all linked to the environment beyond the site's boundaries.
  - Water logging in Guwahati ?
- Intra and intergenerational equity
- Disaster Proneness of Cities
  - Chennai Floods?
- Time Management

Bora, A. (2018) Sustainable Construction and Roadmap ahead

Why Construction sector?

- Today India is the second fastest-growing economy in the World & construction industry is the country's second largest economic activity after agriculture.

- In India construction constitutes 40% to 50% of India's capital expenditure on projects in various sectors such as highways, roads, railways, real estate, energy, airports, irrigation, etc
- However, this sector is also one of the most unorganized sectors in India and faces huge shortage of skilled workers on the construction sites.
- As per National skill development council, the majority of the workforce at approximately 83% constitute unskilled worker, Most of these unskilled workers are seasonal, migrant workers from poorer agricultural states

Bora, A. (2018) Sustainable Construction and Roadmap ahead

Why Construction sector?

- The construction industry and its activities are responsible for a substantial amount of global resource use and waste emissions

- The construction industry, as one of the largest and most important industries and at the same time one of the largest polluters,
- Built environment is also the largest emitter of the greenhouse gas (GHG) emissions thus significantly contributing towards the causes of climate change.
  - construction consumes 40 percent of the raw stone, gravel, and sand used globally each year, and 25 percent of the virgin wood. Buildings also account for 40 per- cent of the energy and 16 percent of the water used annually worldwide.
  - Finally, unhealthy indoor air is found in 30 percent of new and renovated buildings worldwide.

Bora, A. (2018) Sustainable Construction and Roadmap ahead

Why Construction sector?

- Needs to recognize the link between Construction sector and sustainable development
- Needs to relate in one way or another to the creation of built environment and human settlements and their performance
  - To make our cities, towns and villages healthy, safe, just and sustainable
  - Creating a built environment that is sustainable for present as well as for future generations.
  - Human settlements are increasingly vulnerable to natural, human-made and technological risks threatening the livelihood, health and lives of people.
- By 2050, 70 % of the world's population will live in cities
- Some major threats to the safety and security of cities, which are:
  - natural and human-made disasters
  - urban crime and violence, insecurity and forced evictions

Bora, A. (2018) Sustainable Construction and Roadmap ahead

An International Conference on 12-14th Dec 2018 on Smart Villages and Rural Development

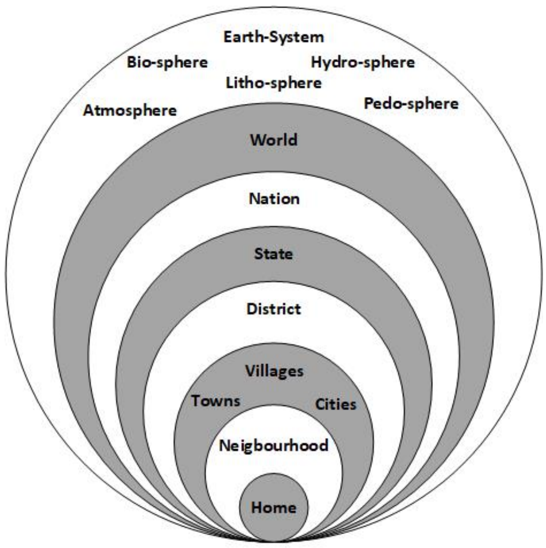


Figure-Village within a World and Earth System

construction sector is critical for creation of smart and sustainable villages and cities

Figure-Developed by Author as a part of his book

Our Mission on Multi-skilling and Sustainability Initiative

- **Calendar of specific courses for up-gradation of skills in the construction sector of the state**
- **To continue the training courses throughout the year with many relevant need-based topics.**
- **Construction Sector**
- **ICT**
- **Sustainability**
- **We seek participants batch by batch from all working Engineering Departments**
  - **Institutional Mechanism for implementation**
  - **ME course in Construction Management**
  - **Other research**

THANK YOU!

Growing Capacity in Assam

Construction Management Course (AEC)

Course Structure			
Specilisation 1 **Sustainability Management**	*Specilisation 2* **Cost Management**	*Specilisation 3* **Project Management**	*Specilisation 4* **Building Construction & Technology**
Common Core Subjects			
Introduction to sustainability	**Building Services and operations (SB)**	**Fundamentals of project management (PB)**	Construction Materials **(BT)**
Specialisation Core Subjects			
Sustainable Solutions for Building (SB)	Building Regulations **(JP)**	Contract Management **(JP)**	Construction Law
Sustainable Materials and Performance	Construction Law	Project procurements	Building Construction **(BT)**
Construction Waste Management (PB)	**Construction Methods and Equipment (SB+PB)**	Project Monitoring and Control	**Construction Methods and Equipment**
Open Elective	Open Elective	Open Elective	Open Elective
Elective Subjects			
Laws and regulations for sustainability	Cost planning and budgeting	Project Finance and Economics **(SKD)**	Building regulations
Environmental Risks and Impacts Assessments	Measurement and Estimation	Construction Planning	**Construction Methods and Equipment**
Social Sustainability Analysis	Cost monitoring and control	Project Risks and quality management **(SKD)**	**3R in Construction (BT+ JP)**
Building regulations	Project procurements **(SKD)**	TBA	TBA
Research Project	Research Project	Research Project	Research Project

SB – Sasanka Bora
PB – Pradip Baishya
JP – Jayanta Pathak
BT – Bipul Talukdar
SKD – Sudip Kumar Deb

Academic Calendar 2019

Construction Management Short Courses for Professionals

A competency based skill development initiative through

MULTI-SKILLING AND SUSTAINABILITY CENTRE of AEC

Sl no.	Training Topics	Course fee	Duration (days)
1	Project Financial Modelling Techniques & Evaluation	TBA	2
2	Fundamentals of project Time Planning and Control using scheduling technique such as Critical Path Method (CPM)	TBA	2
3	Project Schedule development using Microsoft Project (MSP) Software or similar products	TBA	2
4	Project Risk Analysis and Value Engineering	TBA	2
5	Preparation of Detailed Project Report (DPR)		
5.1	Fundamentals of Project feasibility Study and Preparation of DPR	TBA	2
5.2	Procurement, EOI and Tendering	TBA	2
5.3	Preparation of DPR and Tender documents for Sewerage Projects	TBA	2
5.4	Preparation of DPR and Tender documents for Solid waste Management Projects	TBA	2
6	Construction Delay Analysis	TBA	2
7	Construction Materials (Roads & Buildings)	TBA	2
8	Understanding of Building Regulations	TBA	2
9	Multi-hazard Risk Analysis of project	TBA	2
10	Contract practice and administration	TBA	2
11	3R (Repair, Rehabilitation & Retrofitting)	TBA	2
12	Understanding of basic operation and services to be provided in building	TBA	2

13	Project Time Planning and Management	TBA	2
14	Project Resourcing and Direct & Indirect Cost Estimate	TBA	2
15	Risk & Contingency Management	TBA	2
16	Human Resource and Project Monitoring	TBA	2
17	Project Management in Construction	TBA	2
18	Waste management in Construction	TBA	2
19	Solid Waste Management (SWM) rules for disposal of C & D waste in India & Managing municipal waste- An economic perspective	TBA	2
20	Economics & Life cycle assessment of Solid waste management	TBA	2
21	Construction Methods and Equipment	TBA	2
22	Quality Control & Quality Assurance	TBA	2
23	Planning and Design of Drainage System	TBA	2
24	Planning and Design of Sewerage System & Seepage management	TBA	2
25	Planning and design of Water Supply projects	TBA	2
26	Understanding of Public Private Partnership model and Affordable housing	TBA	2
27	Understanding of Greenfield Development and Urban Transport in Smart Governance	TBA	2
28	Pavement Evaluation Techniques and their application for Maintenance and Rehabilitation	TBA	2
29	Design, Construction and Maintenance of Flexible and Rigid Pavement	TBA	2
30	Purchase policy and procedure in Governance and Risk & Contract management in Govt. Dept, Autonomous Bodies and PSUs	TBA	2
31	Understanding of Cost effective New and Innovative methods of Construction Materials for disaster resilient building construction	TBA	2

Objectives

- Conceptualisation of processes within the T&C Planning operations

- Understanding the inefficiencies

- Devising solutions for performance improvement in projects (in both Construction Management and Project Management contexts)

[*Based on a well developed Scientific Methodology known as Soft Systems Methodology (SSM) (Checkland 1981)*]

Available online at www.sciencedirect.com
ScienceDirect
International Journal of Project Management 29 (2011) 622–636
International Journal of Project Management
www.elsevier.com/locate/ijproman

Understanding stakeholders' perspective of cost estimation in project management

Hemanta Kumar Doloi*

Faculty of Architecture, Building and Planning, The University of Melbourne, Parkville Campus, Melbourne, Victoria 3010, Australia

Received 30 January 2010; received in revised form 17 May 2010; accepted 1 June 2010

Abstract

Cost overrun is a chronic problem across most projects. While a significant research have been published on this topic, the understanding of the root causes and a clear direction towards improvement remained unexplored. The focus of the past research is mainly on the factors directly or indirectly associated with the project environment and their relative impacts on overall cost performance in projects. In contrast to such traditional approach, this research aimed to establish a conceptual model by identifying the underlying issues associated mainly with the perceptions of the board stakeholders involved over entire lifecycle of projects. Based on a structured interview with a few selective organisations, data was collected and a few rich pictures were developed over every phase of project development. By employing the soft system methodology, the rich pictures were later trasformed into the concept models for potential establishment of a new body of knowledge in the field. Among the findings, it has been revealed that at the project inception stage, political and legislative factors play significant roles in the business case development. Statutory compliance and environmental issues are perceived to be critical in influencing cost performance in projects. The resulting concept model on cost overrun is expected to fill a significant knowledge gap in cost estimation practice across all industry sectors.

Keywords: Cost overrun; Stakeholders; Soft system methodology; Project management

1. Introduction

A research report focusing on the failure of software projects highlighted a survey where almost one third of sampled projects experienced cost overruns of 150–200%, with an average overrun of 189% of the original cost estimate. Over one third also experienced time overruns of 200–300%, with an average overrun of 222% of the original time estimate (The Standish Group Report, 1995). Similarly, there is a strong consensus among construction industry professionals that the traditional cost estimation approach does not work (Yeo, 1989, 1990; Robinson, 1986). Due to increasing interest among the stakeholders from project owners and suppliers to end user and facility managers in modern construction projects, accurate estimation of cost budgets is a difficult task. Many times there is neither enough data nor adequate time and resources available to prepare an accurate cost estimate. Even when the cost estimate is done correctly, the senior management may determine that the costs are too high resulting in cost reductions without a corresponding reduction of the project scope. Senior level management traditionally provides a top-down cost estimate starting with an understanding of how much there is to allocate to a given project. Unfortunately, the consequences of cost overrun are often borne by the end users (or the public) by way of imposing extra margins on the services delivered. This is particularly evident in the operation of social and economical infrastructure projects delivered through Public–Private-Partnerships (PPP) or Private Finance Initiatives (PFI) across many countries including Australia and the UK.

The above factual evidence clearly shows a gap in current cost estimation practices across the board and highlights the need for reconsideration and potentially re-establishment of a concept model. To this effect, the main objective of the research entails understanding the changes of project environment and

* Tel.: +61 3 83448724; fax: +61 3 83445532.
E-mail address: hdoloi@unimelb.edu.au.

0263-7863/$ - see front matter © 2010 Elsevier Ltd. and IPMA. All rights reserved.
doi:10.1016/j.ijproman.2010.06.001

the emergence of complexity in cost estimating processes in order to assess their impacts on society and the economy and devising strategies for realistic cost management. A conceptual model has been developed by integrating existing and new knowledge in risk management, cost estimating and management processes in projects. By applying the soft system methodology (SSM), cognitive mapping of the decision makers for better understanding of the pathways and potential coping mechanisms for realistic cost planning and controlling practices have been captured (Checkland, 1981; Winter, 2006). The resulting concept model is expected to provide hands-on training to relevant professionals for the capacity building on the improved cost estimating processes across the industry.

2. Background review

Cost estimation is of great importance in project management as it provides substantial information for decision making, cost scheduling and resource management (Carr, 1989). Analogy cost estimation techniques, such as Constructive Cost Modelling (COCOMO), involves employing cost profile data from historical projects that are similar in design or operation, and calibrating the cost of current system based on the software metric differences such as size and capacity. This approach heavily depends on the availability of information from previous projects and thus lack of reliable data often results in the inaccuracy of cost estimating. Parametric cost estimation is an alternative to analogy cost estimation which involves converting base information into parametric input and is capable of producing more accurate cost estimates. However it does not account for the detailed individual components and the workflow in the system (Frank, 2002).

While both analogy and parametric models are based on "top-down" cost estimation, more accurate cost estimates can be achieved by bottom-up processes, which estimating the costs of individual components and totalling them up to produce the final cost estimate (Young and Markley, 2008). However, none of these techniques can be considered robust in terms of both data input requirements and degree of accuracy. The first systematic evaluation of the accuracy of cost estimates was conducted by Morrison in 1984 (Morrison, 1984). In the study, accuracy of cost estimates was measured by the deviation from the lowest acceptable tender in the project. Factors that affect the accuracy were identified as the variability of lowest tenders, the source of cost data used in estimating, the inherent error attached to the estimating technique and the suitability of cost data, in the order of importance. It was suggested that using previous cost data from projects where quantity surveyors have had experiences and using single source of cost data is likely to improve the accuracy of cost estimates.

In the UK, Akintoye and Fitzgerald (2000) investigated current cost estimating practices of contractors for the construction projects. The survey from 84 building firms showed that the contractors use cost estimating mainly for construction planning purposes rather than construction project evaluation. In the cost estimating practice, recent cost estimating techniques (e.g. range estimating and parametric estimating) have not been widely adopted. From the survey, they concluded the major causes of inaccuracy in cost estimating as "the lack of practical knowledge by estimators, insufficient time for cost estimating, poor tender documentations, and the broad variability in subcontractor's prices".

In Australia, Aibinu and Pasco (2008) examined the accuracy of pre-tender building cost estimates by investigating 56 projects and surveying 102 firms. They found that estimation in construction industry in Australia is largely affected by the size of the projects. In small projects, the cost is normally over-estimated by a large amount rather than underestimated. Moreover, the accuracy of estimation has not improved over time, which implies that lack of experience plays a trivial role in biased cost estimation. They suggested better estimation practice by "probability estimation and simulation of past estimates, reducing quantity surveying and cost engineering skill turnover, incorporating market sentiments into estimates, early involvement of the quantity surveyor at the brief stage, and proper documentation of experience gained in the estimation of projects".

In the United States, a comparative study conducted by Flyvbjerg et al. (2002) on actual and estimated costs showed that the costs in transportation infrastructure projects were significantly underestimated. The investigation from 258 transportation infrastructure projects indicated that 86% of cost estimation was overwhelmed, and actual costs were on average 28% higher than the estimates. Statistical analysis suggested systematic bias exists in cost estimation, which results from not only technical cause, but also from psychological/political reasons.

Nassar et al. (2005) conducted a study to evaluate construction cost escalations of asphalt paving operation in the United States. Based on 219 asphalt paving projects in Illinois during the year 2000, the causes of cost overruns were identified using statistical process control techniques (SPC). In their study, the major reasons for cost overruns were recognized as unpredicted additions, balanced final field measurement, and hazardous/controlled waste investigation and cleanup. Moreover, it was demonstrated that SPC analysis is powerful in managing and controlling project costs.

Having reviewed the above selected literature, it has been evident that cost overrun is a widely published topic among researchers. While numerous models and methodologies have been developed over past years on dealing the cost estimation and managing escalations in projects, there is still a significant knowledge gap emerging in establishing a reference or base model for improving the practices across the industry. This research aims to fill this gap by firstly analysing the underlying factors associated with the major players involved in project development environment from a cognitive perspective and then establishing a conceptual model covering all the phases over project life cycle. The remainder of the report will focus on the use of a cognitive methodology namely soft system methodology (SSM) in order to transform a fuzzy and unstructured picture into a realistic concept model in cost estimation practice (Checkland and Scholes, 1990).

In this study, the underlying propositions to be tested are as follows:

1. Existing assumptions, attitudes (psychology) and methods in respect to project cost estimation are inadequate to cope with the complex and emergent nature of modern large scale projects which inevitably leads to consistent project cost under-performance and excessive overruns.
2. The "normal" cost estimation processes and methods are considered to be weak and flawed and are beginning to yield for more efficient and less costly approaches to achieve the same, or superior results.
3. There is a need to re-think and 're-engineer' the existing or normal cost estimation process incorporating emergent diversity and complexity especially in project delivery approaches.

The first proposition focuses on the shortfalls of traditional practices of cost estimation, understanding the underlying issues of handling uncertainties and overall failure in achieving the target performance across projects. Understanding the cost estimation processes from the perception of the key stakeholders is the key element towards validation of this proposition. The second proposition attempts to highlight the point that application of established scientific techniques for cost estimation is not necessary to result into the best possible outcome in every project. This objective is particularly important for all the parties (namely main contractors, client and consultants) to consider the intangibles for developing adequate and realistic estimations in order to obtain the desired outcomes in projects. The third proposition is significant in establishing a comprehensive predictive model to highlight the links between the emergent diversity and complexity in the context of successful project outcomes.

As the current research is centered towards constructing the conceptual models on project overrun, the above propositions are not expected to be validated as research hypotheses in quantitative terms. However, qualitative validity of the propositions will allow reserachers to establish models for relevant quantative analysis. It is anticipated that the overall results will provide a clear insight to the affect of the cost estimation focusing on the products, needs, motivations, environment and strategic business intents. By increasing each discipline's knowledge in meeting requirements and expectations of all the stakeholders, it may be possible to overcome the shortfalls of current cost estimation related problems within the construction industry.

3. Methodology and approach

In this research, the soft system methodology (SSM) has been employed for problem analysis which is based an accurate identification of problems and thoughtful articulation of the current industry situations in view of the consistent cost overruns in major projects (Winter, 2006). A preliminary reference model has been developed to form a basis for comparison with the real situations in order to identify areas of weaknesses. Based on the thorough literature review, a set of questions was presented to the selected participants in order to capture the perceived cost estimation and management practices in projects. By conducting structured interviews in Australian construction industry, the collected responses are then used to develop a conceptual model to compare and contrast with the available best practice established in the field.

3.1. Soft system methodology (SSM)

From the above literature review, it is indicated that the accuracy of cost estimation is affected by a number of qualitative factors from political, economic, technical and behavioural perspectives. Traditional system analysis methodology fails to model this kind of systems since it involves a number of intangible factors which are not clearly defined. Soft system methodology (SSM) is a system approach aimed to analyse systems with complex and less clear-cut characteristics (Winter, 2006). SSM is based on systems thinking, which explores problems in the context of holistic system, and focuses on viewing the interactions between components of systems, rather than investigating the isolated components, as proposed in the philosophy of scientific reductionism. Systems theory suggested that a complex system can be appreciated and modelled by integrating the perceptions of different people involved in the system (Andrews, 2000). Later this idea was formulated further into a practical SSM methodology in order to help understanding the complex and "messy" problems in the real world situation (Checkland, 1981).

3.2. Stages involved in SSM analysis

SSM involves seven distinct stages to analyse complex and organizational situations in the real world. As illustrated in Fig. 1, the stages of applying SSM include:

1. Investigate the unstructured problem and make a proposal of the problem situation. This is the initial stage where problem owners are aware of the problem situations or space for improvement, and start off the analysis.
2. Express the problem situation in the format of "rich pictures". After proposing the problem situation in stage 1, the information of the problem situation is collected, including the structure of the organization, processes and transformations in the system, and issues proposed by organizational members (Checkland and Scholes, 1990). The information is then illustrated in the format of rich picture, which is a graphic representation of the manner one may think about the system.
3. The rich pictures from different organizational members is integrated together to generate an overall rich picture containing perspectives from different organizational members. The root definition can be inferred from the overall rich picture by naming the relevant systems and identifying the input, output, as well as the transformation process. From a well formulated root definition, six key elements can be drawn out, as proposed in the mnemonic CATWOE.

		Checkland and Scholes' description	Agency Context
C	Customers	The victims or beneficiary of T	Public
A	Actors	Those who will do T	Staff
T	Transformation process	The conversion of input to output	Managers
W	Weltanschanung	The world's view which makes T meaning in context	Vision and values
O	Owners	Those who would stop T	Staff and managers
E	Environmental Constraints	Elements outside the systems which it takes as given	Stakeholders
Source: adopted from Checkland and Scholes (1990)			

Fig. 1. Procedures of applying SSM.

4. The root definitions represent the objectives that our system has to achieve. Conceptual model is a model of the minimum set of activities to conform the objectives identified in root definition. The conceptual model in this stage is only the perceptive model in our mind, therefore it does not have to include too many activities until the real world is analysed.
5. At this stage, the real world expressions, as shown in the rich pictures in stage 2, are compared with the conceptual model generated in stage 4. The comparison may lead to re-iterate of previous stages. By trial and error in stage 5, a conscious, coherent and defensible model can be accomplished.
6. In the last two stages, desirable changes and feasible activities are identified and implemented. The changes can occur in the following aspects (Couprie, 2007):

- changes in structure, which applies to the elements of reality in the short term;
- changes in procedure, which applies to the dynamic elements;
- changes in attitude, which applies to the behaviour of various roles.

4. Data collection

In order to investigate the root causes of cost overruns in projects, the first step was to capture the perceived knowledge by the industry practitioners across large Australian construction organisations. For a clear understanding on the effectiveness of cost estimation practices across project development phases, large amount of documented data on completed projects is required. However, due to non-accessibility of the documented data on locally completed projects for this study, a semi-structured interview approach was considered as the most efficient tool. By conducting the interview with the selected professionals practicing in medium to large size design and construction firms, the impact of various attributes on the cost estimation practices and the overall outcomes of the projects have been established.

4.1. Identification of attributes

While the published reports evident a significant similarity in identifying the critical attributes in cost estimation practices across the industry, preparation of a list of comprehensive attributes was a critical first step for the success of this study. By conducting a systematic background review, the significant attributes associated with cost estimation that impact the overall project outcomes have been identified. In this research, the attributes refer to the variables representing a range of capabilities impacting cost estimation and cost performance in the context of overall success in projects. A pilot study was also conducted with a developer and a contractor for clarifying and refining the questions before the interviews were undertaken with the remaining groups. A set of questions covering 13 key attributes over entire project lifecycle was designed to identify the industry cost estimation. To guide the respondents for better understanding of the questions and appropriate structuring of their responses across the issues, these 13 key attributes were communicated prior and expanded further during the interview process. The base data was then gathered to facilitate the qualitative analysis on the responses to work out a meaningful relationship among the attributes and establish the stated reference models.

4.2. Respondent's profiles

The respondents for the interview were selected from a wide range of design and construction teams engaged in developing medium to large size projects in Melbourne. Some of the key criteria use to select the representative respondents are: size/scale of organisation, market reach across sectors, profile of the organisation in the market place, credibility of the organisation, experience of the interviewee and the qualification of the interviewee to respond, sample diversity such as construction, civil, land development and property finance and investment.

Total of six key respondents from six selected firms were contacted for the necessary interview. All the respondents identified had experience working with contractors, consultants, owners and subcontractors in projects. Table 1 shows a typical profile for the respondents used in the study. In order to get the best possible response commensurate by the experience and expertise, introductory conversations and email contacts were made to each respondent to explain and make the objectives of the research clear. Following this introduction, the semi-structured interview questions were issued either in hard copy format or electronically via email. The interview was then conducted in two phases, firstly to gather the firsthand data from the initial interview and secondly the refined data based on the preliminary findings and reflections out of the first interview transcript. Though the sample size is relatively small, the quality of the responses was considered to be highly reliable for the

Table 1
Respondent's profile.

Sl no.	Title	Year of operation	Type of projects(s)	Contract types(s)
1	State business manager	40+	Major contractor	Major capital works type contracts
2	Senior project manager	15+	Major contractor	Major capital works type contracts
3	Manager Victoria	30+	Land developer	Major capital works type contracts
4	Director	3–5	Investor	Contract types with land owners and contractors
5	Director	20+	Financier	Coordination & Management of contract documents on behalf of clients
6	Senior relationship manager	70+	Consultant	Contract relationships with clients

analysis due to relevant industry experiences, personal level interactions and clear understanding of the questions among the respondents (Vaus, 2001).

As seen, amongst the respondents, one was the state business manager with over 40 years of experiences and one project manager with over 15 years experience involved in major capital projects with large construction firms. The rest of the respondents includes a manager with a land development firm with over 30 years experience, two directors, one as an investor with 5 years experience and the other as a financier with over 20 years experience respectively and one very senior relationship manager as the consultant. In order to have appropriate representation of the industry practices, it was important for the participating organisations to have scale, reputation and credibility in the market. It was also determined that the interviewee had the delegated authority to be able to respond on behalf of the organisations and also having the project management experience to be able to respond with authority to the questions.

5. Data analysis

The following is a descriptive analysis of the issues that emerged from the interview process leading to the collection of the data.

5.1. Descriptive analysis

Based on the initial data gathered from the respondents, the emerging themes/patterns have been interpreted along the following key areas:

(i) Market conditions
Market conditions were one of the most critical attributes perceived by all the respondents in the interview process. Throughout the latter part of 2008 there was a significant adjustment in the economic conditions. All of the interviewees commented on the slide in the economy and the difficulty in the market. All of the responses contained a very cautious response to the market as a result of the change in market conditions.

(ii) Site conditions
Each of the interviewees described site conditions as a major factor in cost estimation. The nature of site conditions included contamination, remediation, authority approvals and processes and several other factors. There was a commonality amongst these responses.

(iii) Project complexity
Each of the interviewees was interviewed because of their capacity and involvement in major, complex projects. The role of project complexity in cost performance was asserted as critical by all the interviewees' significant track records and history of involvement in complex projects.

(iv) Design complexity
Each of the interviewees was able to respond to the role of design complexity due to their involvement in complex projects with sound experience in designing of suitable systems to respond to the complexity of projects. Appropriate consideration of the design complexity was perceived to be highly critical among all respondents in the cost estimation process.

While the descriptive analysis provides a good base to identify the prevailing issues perceived by the respondents out of their experience, such analysis unable to highlight the relative criticality of the attributes and their cross-dependent links associated with the human related activities in the project development environment. Addressing these challenges, soft system thinking seeks to explore the 'messy' problematic situations that arise in human related activity. The soft system allows interpretations of the problems and the picturise the interfaces gained in the interview process and the responses to the problems as drafted by each of the interviewees. The following section will focus on the application of the soft system methodology and resulting concept models.

5.2. SSM application

As a first step of applying the SSM, rich pictures are developed to represent the real work situations based on the raw dataset and preliminary analysis. According to the SSM procedures depicted in Fig. 1, the interviews from different perspectives of cost estimation were conducted to develop the relevant rich pictures for representing the concept maps of the stated cost estimation practice. It is worthwhile to note that each of the interviewees was interviewed because of their ability to respond to complex project environment in order to capture the cognitive processes into the rich picture format. Thus, the ability and vision of the interviewees were drawn out through verbal response and then into a graphic interpretation. From the development of individual rich pictures on the broad concept, further mapping were performed to develop the detailed rich pictures for each stage of the process from project inception through to tendering and initiation. The rich picture forms a basic model which is then developed into a basic conceptual model then in turn forming a broader conceptual model of the reality of the market.

From the rich pictures the problems are then be defined as root definition by identifying CATWOE, namely the customers, actors, transformation, weltanschauung (world view), owners, and environmental constraint of the problem (refer to Fig. 1). Following sections discuss the rich pictures over inception, tendering and initiation stages of projects. During the interview process, rich pictures were also developed over project execution and handover phases but these pictures were not found to be significantly difference from the inception phase. Thus, rich picture for inception phase was considered as a good representation of the rest of the succeeding phases without notable variation. By performing the CATWOE analysis, the root definitions for cost overruns in project inception stage, tendering stage and initiation stage are discussed in tabular form.

5.3. SSM over project inception stage

Fig. 2 depicts the resulting rich picture on effect of cost estimating and management practices at an inception phase of the project. The images in the picture show the parties or stakeholders directly or indirectly associated in the project inception phase.

While the dotted arrows show the weak or distant links, the solid arrows represent the strong links between the parties and underlying project attributes. Table 2 depicts root definition of the rich picture (Fig. 2) in terms of CATWOE analysis. As seen, at the inception phase of a project, clients, sponsors and end-users are the key customers with highest stake on the project decisions. The actors list includes, business development team, project manager, bidding team, land developer, consultant, financiers, contractors and sub-contractors who perceived to have the critical roles in terms of influencing on formulation and implementation of the decisions process. The transformation is governed by relevant knowledge, processes and technology that allow identification of

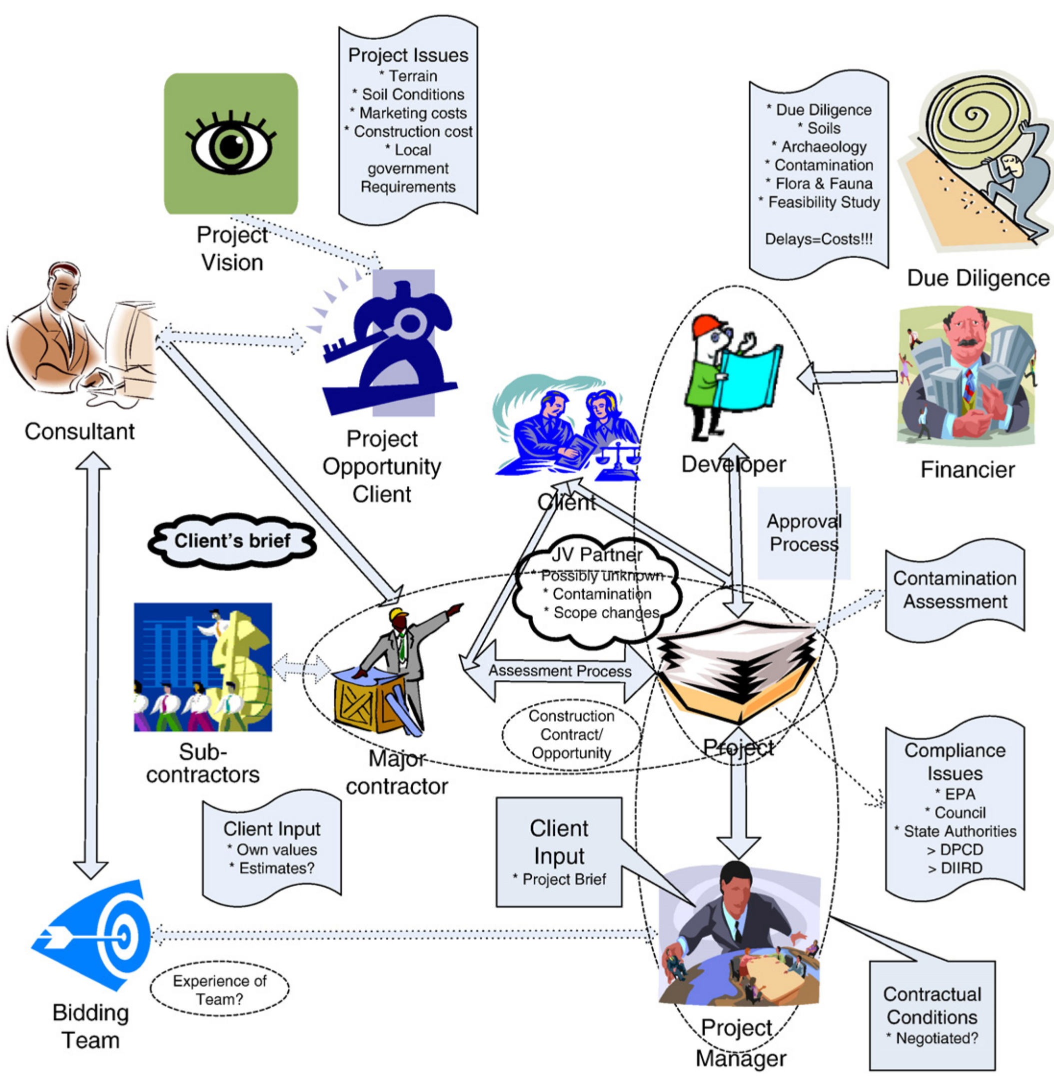


Fig. 2. Rich picture showing effect of cost estimation practices in project inception stage.

Table 2
Root definition in project inception stage.

Element of CATWOE	Module description
Customers	Clients, sponsors and end users
Actors	Business development team, project manager, bidding team, land developer, consultants, financiers, consortium, contractors and subcontractors
Transformation	Knowledge, processes and technology together with identification of the potential causes of cost overruns in project inception stage
Weltanschauung	To ensure accurate cost estimates based on accurate understanding the scope for meeting the stakeholders' expectations
Owners	Project owners, pre-tender teams
Environmental Constraints	Competition, policies/legislations, economic climates, social/environmental concerns, community and corporate objectives

the underlying factors associated with cost estimations and potential causes of cost overruns. Wettanschauung refers to the phrase "why bother" and the root cause being bothered is the inaccurate cost estimation and management that potentially leads to cost overrun in the execution stage of project. The environmental constraints can be represented by underlying competition, political and legislative regulations, economic climates, social end environmental variability, community perceptions and corporate objectives. Therefore, the cost estimation environment at the project inception phase can be represented using CATWOE as depicted in Table 2.

5.4. SSM over project tendering stage

Fig. 3 shows the roles of various stakeholders involved in project tendering stage, and the interactive relationships between them. In the tendering stage, project owner, the sponsors and the tenderer become the key customers in transforming the concept to the reality through effective project delivery. Therefore, the cost estimation at the tender stage requires realistic estimation with reference to the tender bids. Moreover, as the project has been approved from the clients, the tenderers' participation in the bidding process becomes eminent and thus the tenderers become one of the key customers of cost estimation. Since the approval of the project has been obtained, business development team is not responsible for cost estimation anymore in this stage. Instead, major cost estimation work is to be done by the tenderers in order to determine the validity of their bidding potentials. Compared to the inception stage, more detailed cost estimation has to be done in this stage, therefore a number of factors from compliance issues, contractual conditions as well as external forces come into concern (refer to Table 3). All these complications will eventually lead into cost overruns in absence of appropriate integration and ill-practices of risk assessment and management.

At this stage, the roles of subcontractors and their effectiveness in service delivery should be considered through the main contractor's bid. Buildability issues in terms of design complexity and accessibility issues related to the site conditions as well as direct or indirect stakeholders should be thoroughly integrated in the cost estimation process.

5.5. SSM over project initiation stage

Fig. 4 shows the rich picture representing the roles of the stakeholders and relational links among them over project initiation stage. Table 4 depicts the summary of the relevant CATWOE analysis. As seen, after tendering process, appropriate contractors and sub-contractors are chosen, and the project proceeds into the initiation stage. In this stage, the cost estimation is mainly done for the merit of contractors to manage their costs and maximise their profits. Contractual conditions will not be the considerations as all the paperwork has been done in the former stages. Instead, the effectiveness of contract management will be one of the predominant factors leading to cost overruns, especially in long term projects. Besides the factors identified in tendering stage, procurement and delivery strategies become one of the essential causes of cost overrun for the project contractors. In addition, market condition change will potentially lead to a cost overrun which is a paramount factor for consideration at this stage. Availability of the materials and costing for delivery and installation are required to compare with the baseline project plan. Any variations in baseline project plan in terms of scope of the project and market conditions should be clearly integrated in consultation with the customers and actors as shown in Table 4.

6. Development of the concept models

The final step of the SSM methodology is the development of concept models out of the rich pictures and CATWOE analysis over all the respective project phases. By developing the concept models, the processes articulating relational links between stakeholders and associated project related attributes are further refined. The concept models then form a solid base towards establishing the reference models in order for benchmarking the enhanced industry practices. The remainder of the manuscript focuses on the development of the concept models over inception, tendering and initiation phases.

6.1. Concept model over project inception stage

Having identified the actors and the respective factors leading to cost overrun in the rich picture, Fig. 5 depicts the concept model of cost overrun over project inception stage. As seen, for the business development team, who is the decision maker in the project, the incapability of considering the statutory compliance, unawareness of environmental issues, insufficient industrial knowledge, as well as inappropriate definition of project scope/duration will be the major reason of cost overruns. For land owners, they have to consider the due diligence of the tenderers, potential delays in obtaining

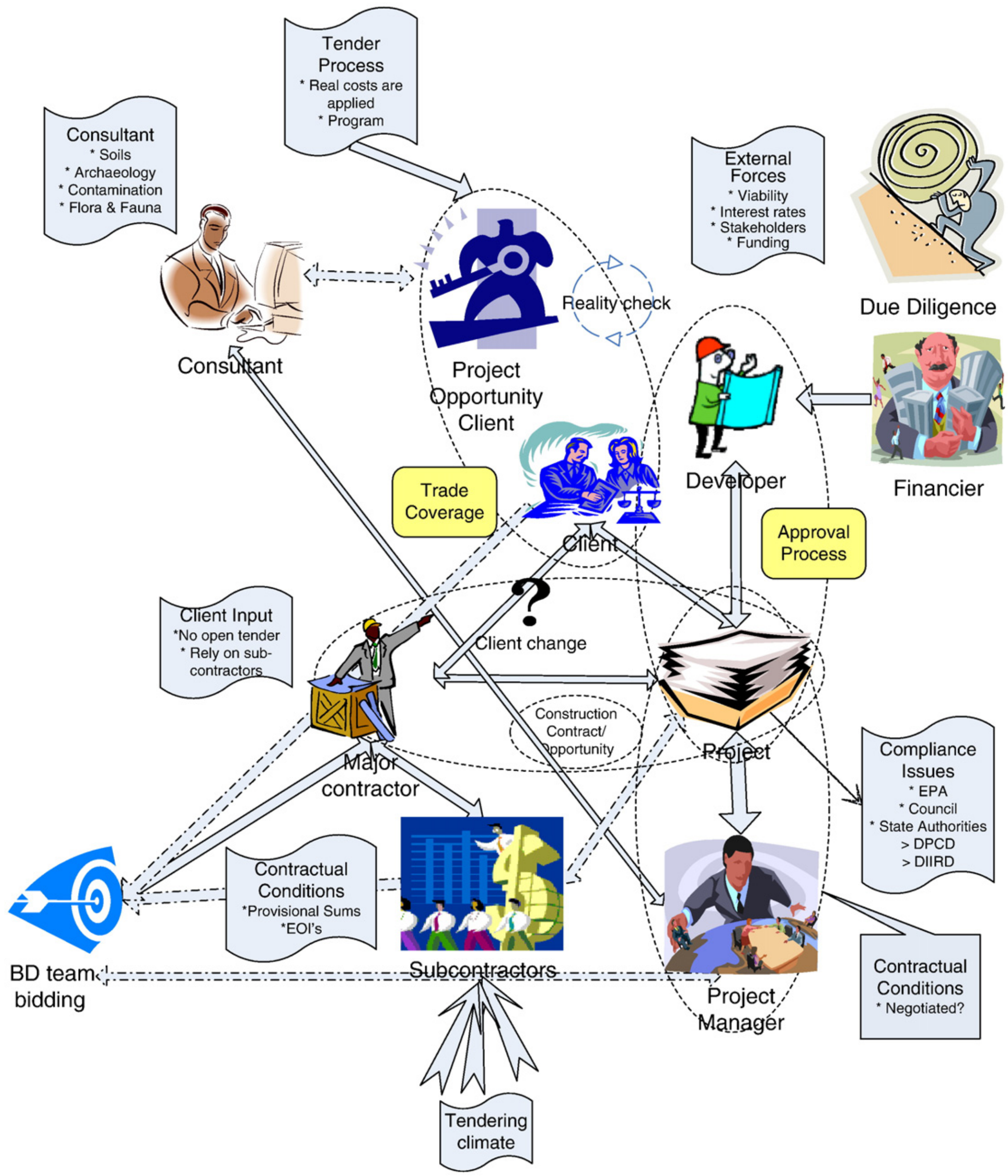


Fig. 3. Rich picture of cost overruns in project tendering stage.

Table 3
Root definition in project tendering stage.

Element of CATWOE	Module description
Customers	Project owners, tenderers and sponsors
Actors	Tenderers, project manager, land developer, consultants, financiers
Transformation	Identifying the causes of cost overruns in project tendering stage
Weltanschauung	To ensure accurate cost estimates for the stakeholders
Owners	Tenderers
Environmental constraints	Policies/legislations, economic climates, social/environmental concerns

government approvals, the financial/funding expectations, etc. As the consultants of the project, they have to be aware of the terrain conditions, construction costs, etc. in terms of cost estimation. Financiers are responsible for funding the project. In terms of improving the cost estimation, they have to pay special attention to details, project feasibility, market conditions, as well as the balance of project management triangles, i.e. time, cost and quality. The accuracy of cost estimation is affected by the experiences of the bidding team and project managers as well. The completeness of project brief, industrial knowledge and experience of PM/DM will greatly affect the quality of cost estimation. Having highlighted the roles of the key stakeholders and their obligations in cost estimation process, the proposition 1 that there is a need for significant alterations of the attitudes,

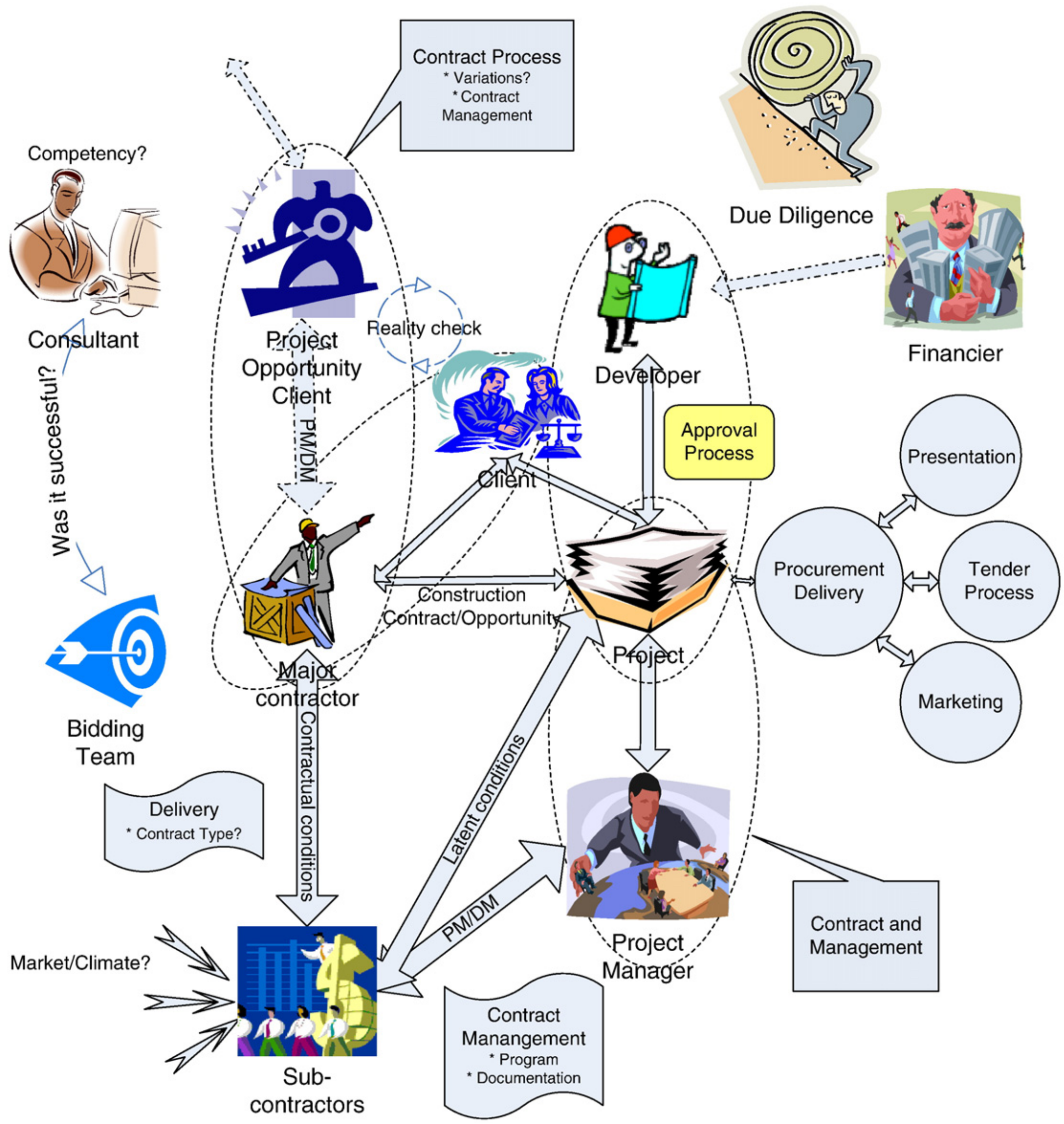


Fig. 4. Rich picture of cost overruns in project initiation stage.

assumptions and methods associated with the typical project cost estimation are fully supported. These radical shifts are found to be one of the key requirements in cost estimation process over the inception stage and hence this assertion supports propositions 2 and 3 as well.

Table 4
Root definition in project initiation stage.

Element of CATWOE	Module description
Customers	Contractors, project owners and sponsors
Actors	Contractors, project manager, land developer, consultants, financiers
Transformation	Identifying the causes of cost overruns in project initiation stage
Weltanschauung	To ensure accurate cost estimates for the stakeholders
Owners	Contractors
Environmental Constraints	Policies/legislations, economic climates, social/environmental concerns

6.2. Concept model over project tendering stage

Fig. 6 shows the concept model at project tendering stage. As seen, when the project proceeds into tendering stage, business development team and bidding team will not participate in the cost estimation. Instead, the tenderers join in the actors group and become the owner of the cost estimation. Supporting the propositions 2 and 3, it has been revealed that environmental and legislative issues remain the sources of cost overrun, whereas unexpected forces from market and economic environment are the new factors causing cost overruns in this stage. In addition, appropriate risk management become more and more essential in terms of avoiding cost overruns.

6.3. Concept model over project initiation stage

Fig. 7 depicts the concept model over project initiation stage. In the initiation stage, as most of the variations in the project are eliminated or mitigated, the factors causing cost overruns in

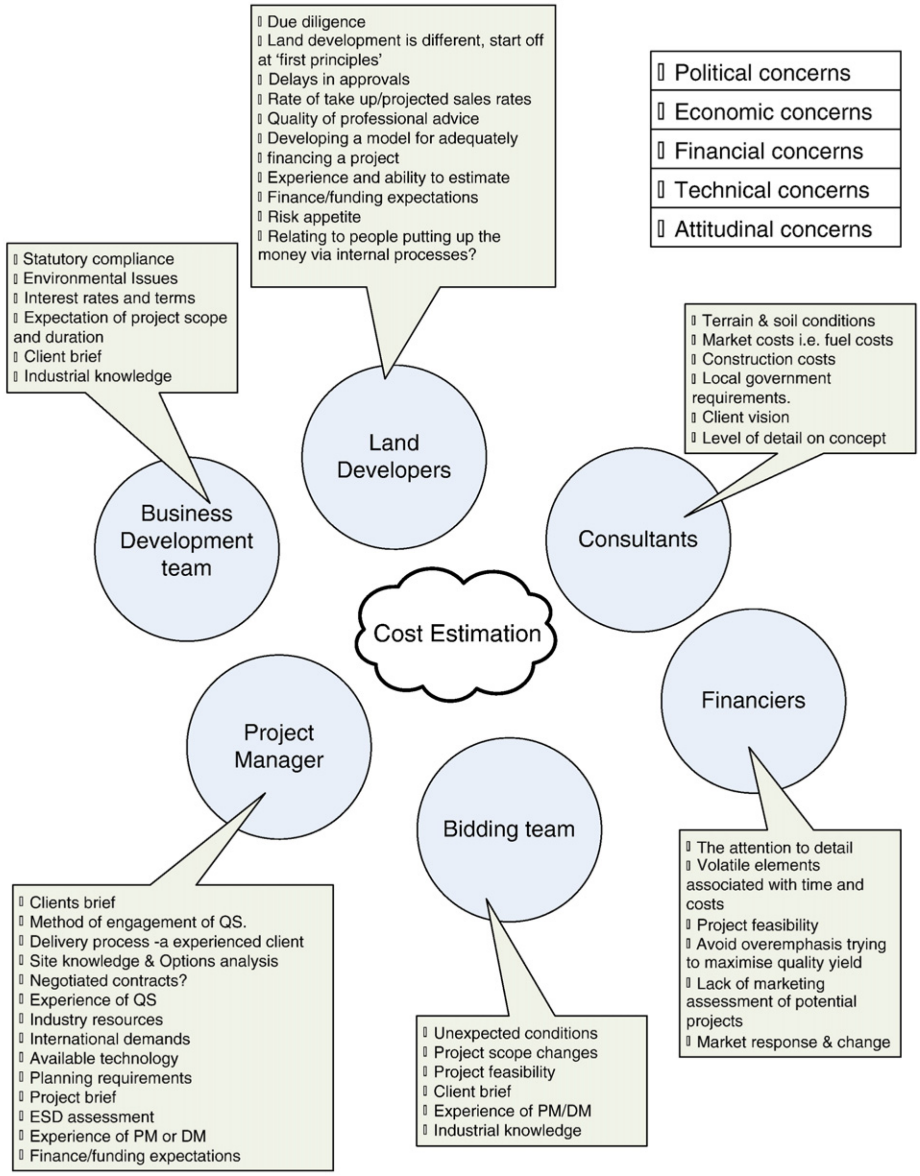


Fig. 5. Conceptual model of cost estimation in project inception stage.

previous stages disappear. The variation of contract and ineffectiveness of contract management will be the major factors leading to cost overruns, in addition with the competency of design team and builders/sub-contractors rise to variations. Highlighting a clear contrast to the traditional approach in the context of project related variations in estimating process, the assertions that contract and administration based variations are the prevailing factors over project initiation stages and beyond support both propositions 2 and 3 (Morrison, 1984; Carr, 1989).

In order to manage the scope variations and ineffectiveness of contractors onsite, appropriate control and monitoring practices become crucial over the initiation phases. Following the initiation phase, appropriate controlling of the baseline project over the subsequent phases for project development namely planning, execution and close out phases is important for effective management of cost performance in the project. To this effect, appropriate strategies for reporting on progress claims and tracking and monitoring the onsite development play significant roles out of project manager's capability in order to achieve seamless delivery and potentially avoiding the cost overruns in the project.

7. Findings and discussions

The factors that affect cost estimation in engineering project can be classified into five major categories: *political*, *economic*, *financial*, *technical* and *attitudinal concerns*. The underlying attributes associated with these five categories against the key project elements have been summarised in Tables 4–6 over all three major phases namely inception, tendering and initiation phases below.

As depicted in Table 5, the results of the SSM analysis revealed that at the project inception stage, the business

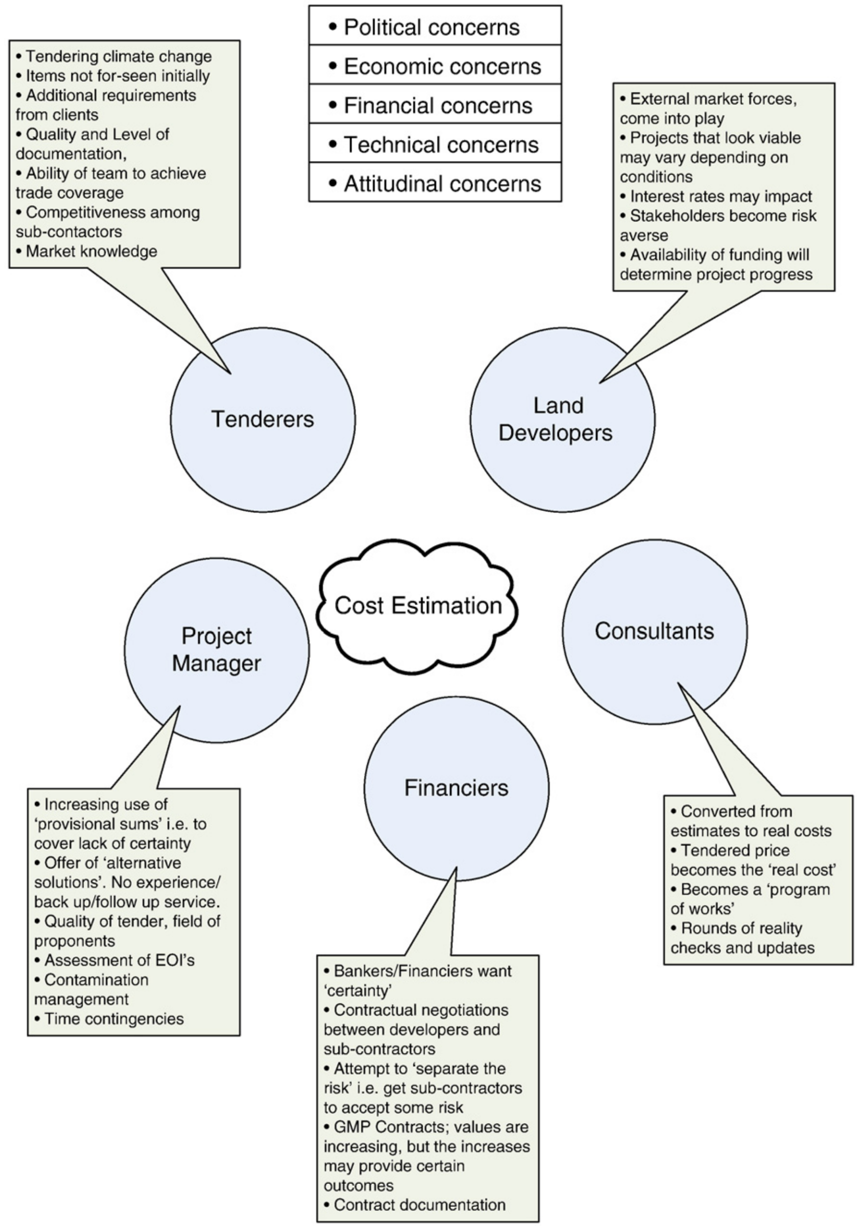


Fig. 6. Conceptual model of cost estimation in project tendering stage.

development team has to take the political and legislative factors into account, such as the statutory compliance and environmental issues. The economic conditions as well as the project scope/duration expectations must be taken into consideration in the early stage cost estimation process. Clear client briefing and relevant industrial knowledge are substantial in affecting quality of cost estimation as well. Project manager is expected to be responsible for estimating life cycle cost and pre-assessing the project at the project inception stage. The quality of cost estimation largely depends on the details specified in clients briefing. This finding contrasts with the results published by Nassar et al. (2005) which contended that cost overruns can easily be prevented through adequate control of cost and quality in projects. In contrast, SSM analysis revealed that early intervention of the key stakeholders in the cost estimation equation significantly reduces the risk of consequential costs in project. This finding fully supports proposition 1 as expected. The assertions that pre-determined engagement method of QS and delivery process effectively avoid cost overruns support both propositions 2 and 3 in this study. The knowledge of the site, the experience of QS as well as competent project management practice will reduce the likelihood of making errors in cost estimation and potentially contribute to the reduction cost overruns. The uncertainties from tenderer perspective at tendering stage include the change of tender climate, emergence of unforeseen factors, change of client's requirements, competition of sub-contractors, etc. In addition, the quality and level of documentation will affect the quality of cost estimation. Lack of market knowledge will lead to cost overrun as well.

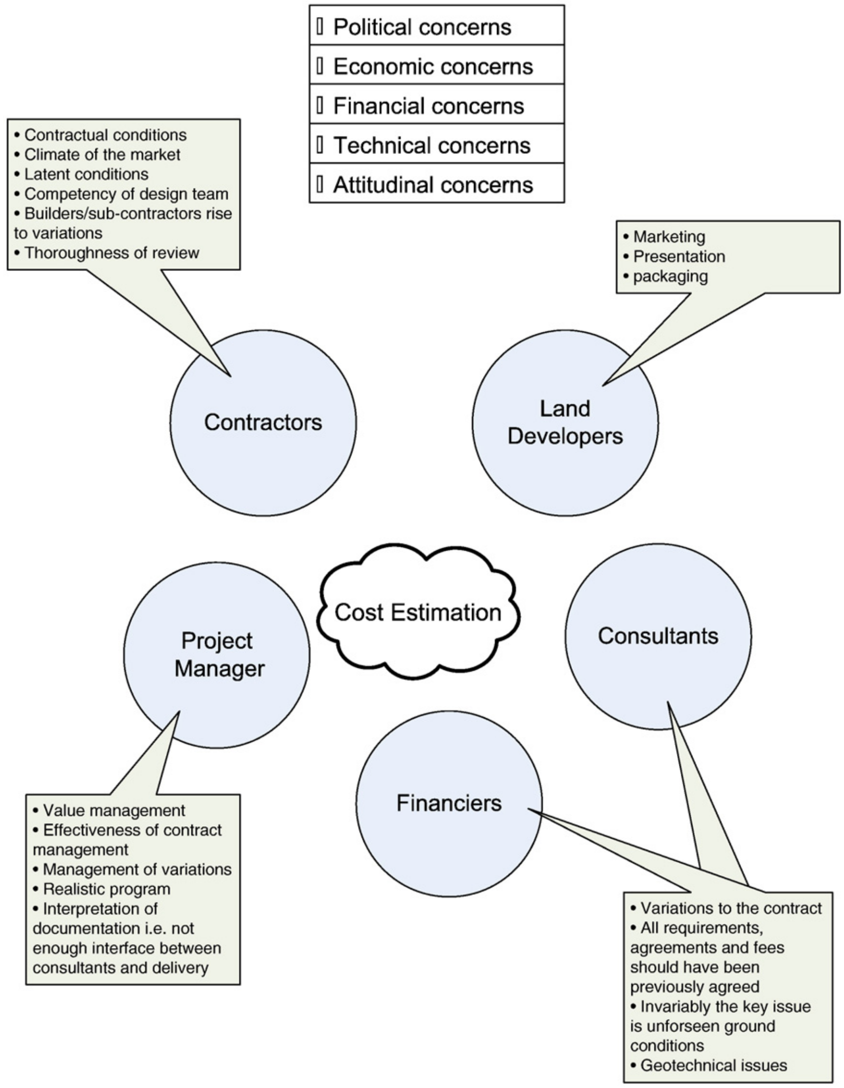


Fig. 7. Conceptual model of cost estimation in project initiation stage.

As depicted in Table 6, in tender stage, cost overruns generally come from the increasing use of provisional sum, offering alternative solutions in the project plan, assessing the EOIs, managing contamination and time contingencies. Quality of tenderer is another factor found to have effects on the accuracy of cost estimation. These findings support proposition 3 that rethinking is therefore a fundamental need for incorporating emergent diversity and complexity in efficient project delivery in the cost management context.

As discussed in Table 7, most of the uncertainties in the previous stages are expected to be eliminated over the initiation stage. However the unexpected contractual conditions, latent conditions and variations to builders/sub-contractors are the common cause of cost overruns. Moreover, market conditions, competency of design team and thoroughness of review will affect previous cost estimation as well. The variations in cost estimation in terms of project management perspective are mainly associated with value management, contract management and management of variations. In addition, project manager has to be aware of the difference between project programs and realistic implementation challenges onsite. Relevant control and tracking mechanisms should be in place for appropriate adjustments in the cost budgeting and project baseline estimates. This finding supports the assertions that effective communication between stakeholders plays a significant role in accurate cost estimation process (Frank, 2002) and hence justifies proposition 1 in entirety. However, in contrast to the findings of Carr (1989), the overreliance on the traditional cost estimating principles alone found to be significantly inadequate in delivering successful cost performance in projects.

8. Conclusion and further research

Cost overrun is a chronic problem across most projects. Increasing complexity of modern and involvement of multitude of stakeholders with varied stakes make it nearly impossible for the modern construction projects to avoid cost overruns. While numerous methods and models have been published on the issue of cost overruns, the root cause associated with the project

Table 5
Description of key elements in project inception stage.

Key elements	Considerations	Discussions
Business development team	• Statutory compliance • Environmental issues • Interest rates and terms • Expectation of project scope and duration • Client brief • Industrial knowledge	In project inception stage, business development team has to take the political and legislative factors into account, such as the statutory compliance and environmental issues. The economic conditions as well as the project scope/duration expectations have to be incorporated to get better cost estimation. Clear client brief and relevant industrial knowledge are substantial in affecting quality of cost estimation as well.
Project manager	• Clients brief • Method of engagement of QS. • Delivery process — a experienced client • Site knowledge and options analysis • Negotiated contracts? • Experience of QS • Industry resources • International demands • Available technology • Planning requirements • Project brief • ESD assessment • Experience of PM or DM • Finance/funding expectations	Project manager is responsible for estimating life cycle cost and pre-assessing the project in project inception stage. The quality of cost estimation largely depends on the details specified in clients brief. Different engagement methods of QS and delivery process will affect cost estimation by and large, therefore pre-determined engagement method of QS and delivery process will effectively avoid cost overruns. The knowledge of the site, the experience of QS as well as competent project management practice will reduce the likelihood of making errors in cost estimation, therefore will reduce cost overruns.
Bidding team	• Unexpected conditions • Project scope changes • Project feasibility • Client brief • Experience of PM/DM • Industrial knowledge	Bidding team is responsible for estimating cost for pre-tendering evaluation in inception stage. Cost overruns for bidding team will be raised from unexpected conditions, changing the project scope, unclearness of the client brief, lack of project feasibility study, as well as experiences of bidding team from industrial and management point of view.
Land developer	• Due diligence • Land development is different, start off at 'first principles' • Delays in approvals • Rate of take up/projected sales rates • Quality of professional advice • Developing a model for adequately • Financing a project • Experience and ability to estimate • Finance/funding expectations • Risk appetite • Relating to people putting up the money via internal processes?	In terms of avoiding cost overruns, Land developers have to consider the source of financial support, risks associated with the project, the adequate financial model, market response of the project, as well as due diligence of the actors. Delay in getting approvals from government is one of the common causes of cost overruns. Moreover, accurate cost estimates are often achieved from experienced QS and good professional advices.
Consultants	• Terrain and soil conditions • Market costs i.e. fuel costs • Construction costs • Local government requirements. • Client vision • Level of detail on concept	More accurate cost estimates from consultants' perspective will depend on the level of detail on concept they consider. The common causes of cost overruns from consultants include failing to consider terrain & soil conditions, market costs, construction costs, local government requirements, etc. Failure in consider the long term vision of clients is a common cause of cost overruns as well.
Financiers	• The attention to detail • Volatile elements associated with time and costs • Project feasibility • Avoid overemphasis trying to maximise quality yield • Lack of marketing assessment of potential projects • Market response & change	The accuracy of cost estimates is affected by the level of details provided to the financiers. The uncertainty of project time and costs, project feasibility as well as market conditions will lead to cost overruns. Another factor that is likely to cause cost overruns is the overemphasis on the quality. Over specification of quality standard potentially impact on increased cost of quality.

development environment impacting cost performance still remains unexplored. Based on a cognitive mapping philosophy and by applying the soft system methodology (SSM), this research explored all the underlying perceptive factors in order to establish a benchmark for managing cost overruns in project. Based on the rich picture representations and relevant concept models, a conceptual model has been established.

The results of the SSM analysis revealed that traditional cost estimating principles are fundamentally inadequate in addressing accuracy in cost managment in modern projects. An early interaction with the key stakeholders and establishment of the clear lines of communications for sharing professional and project based knowledge are crucial over inception phase of projects. The key stakeholders in project inception stage include owner, designer, financier, developer, designer and bidding team. As the project proceeds over to tendering stage, contractor's roles become far more significant in terms of affecting cost performance in project. Incorporation of the contractor's perspectives in terms of legislative and environmental constraints in the estimation process is a crucial element

Table 6
Description of key elements in project tendering stage.

Key Elements	Considerations	Descriptions
Tenderer	• Tendering climate change • Items not for-seen initially • Additional requirements from clients • Quality and level of documentation, • Ability of team to achieve trade coverage • Competitiveness among sub-contactors • Market knowledge	The uncertainties from tenderer perspective in tendering stage include the tender climate change, unpredictable factors, client requirement change, competition of sub-contractors, etc. In addition, the quality and level documentation will affect the quality of cost estimation. Lack of market knowledge will lead to cost overrun as well.
Project Manager	• Increasing use of 'provisional sums' i.e. to cover lack of certainty • Offer of 'alternative solutions'. No experience/back up/follow up service. • Quality of tender, field of proponents • Assessment of EOI's • Contamination management • Time contingencies	In tender stage, project manager has to develop detailed project plan. Cost overruns generally come from the increasing use of provisional sum, offering alternative solutions in the project plan, assessing the EOIs, managing contamination and time contingencies. Quality of tenderer is another factor that affects the accuracy of cost estimation.
Land Developer	• External market forces come into play • Projects that look viable may vary depending on conditions • Interest rates may impact • Stakeholders become risk averse • Availability of funding will determine project progress	The uncertainties for land developers are the external market forces, interest rates, availability of funding as well as the attitude of stakeholders to risk. Contrary to other actors in tendering stage, even if uncertainties will lead to cost overrun, it is necessary for land developers to retain some uncertainties to ensure the flexibility of project.
Consultants	• Converted from estimates to real costs • Tendered price becomes the 'real cost' • Becomes a 'program of works' • Rounds of reality checks and updates	The consultants have to be aware of the difference between the cost estimates and real costs, and convert the estimates to real costs. This involves work breakdown structure and reality checks.
Financiers	• Bankers/financiers want 'certainty' • Contractual negotiations between developers and sub-contractors • Attempt to 'separate the risk' i.e. get sub-contractors to accept some risk • GMP contracts; values are increasing, but the increases may provide certain outcomes • Contract documentation	The uncertainties for financiers come from contractual negotiations between developers and subcontractors, contract type as well as details of contract documentation. Risk management, i.e. risk transfer to other parties in tendering stage will lead to uncertainty and subsequently cost overruns as well.

in this tender development stage. Once the project reaches to the initiation stage and proceeds over to planning, execution and handover phases, contractual variations and contract administration become crucial in terms of resulting cost performance. These findings clearly highlight the needs for not being overreliant on the traditional cost-estimating principles but a radical shift in cost estimation and control of complex projects.

While the outcome of the current research adds a significant contribution to the current body of knowledge in the cost management practice, the research is not excempted from

Table 7
Description of key elements in project initiation stage.

Key Elements	Considerations	Descriptions
Contractor	• Contractual conditions • Climate of the market • Latent conditions • Competency of design team • Builders/sub-contractors rise to variations • Thoroughness of review	In the initiation stage, most of the uncertainties in the previous stages will be eliminated. However the unexpected contractual conditions, latent conditions and variations to builders/sub-contractors are the common cause of cost overruns. Moreover, market conditions, competency of design team and thoroughness of review will affect previous cost estimation as well.
Project Manager	• Value management • Effectiveness of contract management • Management of variations • Realistic program, controlling and tracking • Interpretation of documentation i.e. not enough interface between consultants and delivery	The variations in cost estimation in terms of project management perspective are mainly associated with value management, contract management and management of variations. In addition, project manager has to be aware of the difference between project programs and realistic implementation challenges onsite. Relevant control and tracking mechanisms should be in place for appropriate adjustments in the cost budgeting and project baseline estimates. Furthermore, misinterpretation of documentation leads to cost overruns as well.
Land Developer	• Marketing • Presentation • Packaging	The major responsibility for land developer in project initiation or later stage will be marketing; therefore the cost estimation for them should be focused on marketing and associated activities.
Consultants & Financiers	• Variations to the contract • All requirements, agreements and fees should have been previously agreed • Invariably the key issue is unforeseen ground conditions • Geotechnical issues	Uncertainties such as variation to the contract, unforeseen ground conditions as well as geotechnical issues not formerly considered will lead cost overruns. In addition, to accurately estimate the cost, all requirements, agreements and fees in the initiation stage should have been agreed to which in previous stages.

shortcomings as expected. Among the shortcomings, firstly, the model required further validation with international practices outside the Australian construction projects. Secondly, based on the concept models developed, all the underlying factors need to be tested or hypothesised on relational or structural links in order for the evaluation of the quantitative impacts of each factor on the overall cost performance in the projects. The resulting relational model can then be compared to validate with international practices which can potentially assist in standardising an international practice across the industry. The authors intend to address these two fundamental shortcomings in the near future.

Acknowledgement

The author would like to thank all the respondents of the interviews for their valuable opinions and contributions in the project. The author wishes to extend his sincere gratitude to the trustees of the Royal Institute of Chartered Surveyor (RICS) for their support in sponsoring the project.

References

Aibinu, A.A., Pasco, T., 2008. The accuracy of pre-tender building cost estimates in Australia. Construction Management and Economics 26, 1257–1269.

Akintoye, A., Fitzgerald, E., 2000. A survey of current cost estimating practices in the UK. Construction Management and Economics 18, 161–172.

Andrews, C.L., 2000. Restoring legitimacy to the systems approach. IEEE Technology and Society 19 (4), 38–44.

Carr, R.I., 1989. Cost-estimating principles. Journal of Construction Engineering and Management 115 (4), 545–551 December.

Checkland, P., 1981. Systems Thinking, Systems Practice. Wiley, Chichester.

Checkland, P., Scholes, J., 1990. Soft Systems Methodology in Action. Wiley, Chichester.

Couprie, D., 2007. Soft Systems Methodology. Department of Computer Science, University of Calgary. available at https://internal.shenton.wa.edu.au/ITResources/12InformSys/Information%20Systems/PDFs/Rich%20Pictures.pdf (accessed in March 2010).

Flyvbjerg, B., Holm, M.S., Buhl, S., 2002. Underestimating costs in public works projects. Journal of the American Planning Association 68 (3) Summer.

Frank, A., 2002. Why NASA's management doesn't believe the cost estimate. Engineering Management Journal 14 (1), 7–12 Mar.

Morrison, N., 1984. The accuracy of quantity surveyors' cost estimating. Construction Management and Economics 2, 57–75.

Nassar, K.M., Nassar, W.M., Hegab, M.Y., 2005. Evaluating cost overruns of asphalt paving project using statistical process control methods. Journal of Construction Engineering and Management 131 (11), 1173–1178 NOVEMBER.

Robinson, J., 1986. Life cycle costing in buildings: a practical approach. Australian Institute of Building Papers 1, 13–28.

Vaus, D.A., 2001. Research Design in Social Science. Sage Publications Ltd, London.

Winter, M., 2006. Problem structuring in project management: an application of soft systems methodology (SSM). Journal of Operational Research Society 57, 802–812.

Yeo, K.T., 1989. Order of magnitude capital cost and contingency estimation. The Cost Engineer Journal, UK 27 (6), 458–470.

Yeo, K.T., 1990. Risks, classification of estimates and contingency management. ASCE Journal of Management in Engineering, American Society of Civil Engineers, USA 6 (4), 458–470 Oct.

Young, M., Markley, T., 2008. A better cost-estimating tool: the key to not going over budget. Defense AT&L, July–August, pp. 23–26.

Five case studies applying Soft Systems Methodology to Knowledge Management

Tayyab Maqsood
Doctoral Candidate, CRC for Construction Innovation, RMIT University, Melbourne, Victoria, Australia

Andrew D. Finegan
Lecturer, School of Business Information Technology, RMIT University, Melbourne, Victoria, Australia

Derek H.T. Walker
Professor, CRC for Construction Innovation, RMIT University, Melbourne, Victoria, Australia

Abstract
Construction projects are faced with a challenge that must not be underestimated. These projects are increasingly becoming highly competitive, more complex, and difficult to manage. They become problems that are difficult to solve using traditional approaches. Soft Systems Methodology (SSM) is a systems approach that is used for analysis and problem solving in such complex and messy situations. SSM uses "systems thinking" in a cycle of action research, learning and reflection to help understand the various perceptions that exist in the minds of the different people involved in the situation. This paper examines the benefits of applying SSM to problems of knowledge management in construction project management, especially those situations that are challenging to understand and difficult to act upon. It includes five case studies of its use in dealing with the confusing situations that incorporate human, organizational and technical aspects.

Key words
Construction projects, knowledge management, complex systems, problem solving, Soft Systems Methodology.

1. Introduction

The issue of knowledge management in construction projects is a challenge that cannot be underestimated. Such projects are becoming more complex, they are subject to constant change, and the industry environment is highly competitive and cost critical. The challenge becomes greater where joint ventures, partnerships and sub-contracting agreements are involved. The ad hoc and tradition approaches to construction management often fail to perform in these situations, and managers need to consider adopting alternative approaches to solve these difficult problems.

Soft Systems Methodology (SSM) is a systems approach that is used for analysis and problem solving in complex and messy situations. SSM uses "systems thinking" in a cycle of action research, learning and reflection to help understand the various perceptions that exist in the minds of the different people involved in the situation. It is particularly suited to complex management systems, and seeks to evaluate as many different options as possible. This approach is applicable to many domains; including change management, planning for health and medical systems, information systems planning, human resource management, analysis of logistics systems, and expert systems development. More specifically, SSM is being used in research associated with knowledge management, project management, and engineering and construction management.

2. Soft Systems Methodology

Soft systems thinking seeks to explore the 'messy' problematic situations that arise in human activity. However, rather than reducing the complexity of the 'mess' so that it can be modelled mathematically (hard systems), soft systems strive to learn from the different perceptions that exist in the minds of the different people involved in the situation (Andrews, 2000). This interpretive approach is strongly influenced by Vickers' (1968, pp. 59, 176) description of the importance of appreciative systems in dealing with human complexity. Checkland (1999), and Checkland and Scholes (1990) have attempted to transform these ideas from systems theory into a practical methodology that is called Soft Systems Methodology (SSM). Checkland's premise is that systems analysts need to apply their craft to problems of complexity that are not well defined, and that SSM attempts to understand the wicked and fuzzy world of complex organisations. This is achieved with the core paradigm of learning (Checkland, 1999, p. 258).

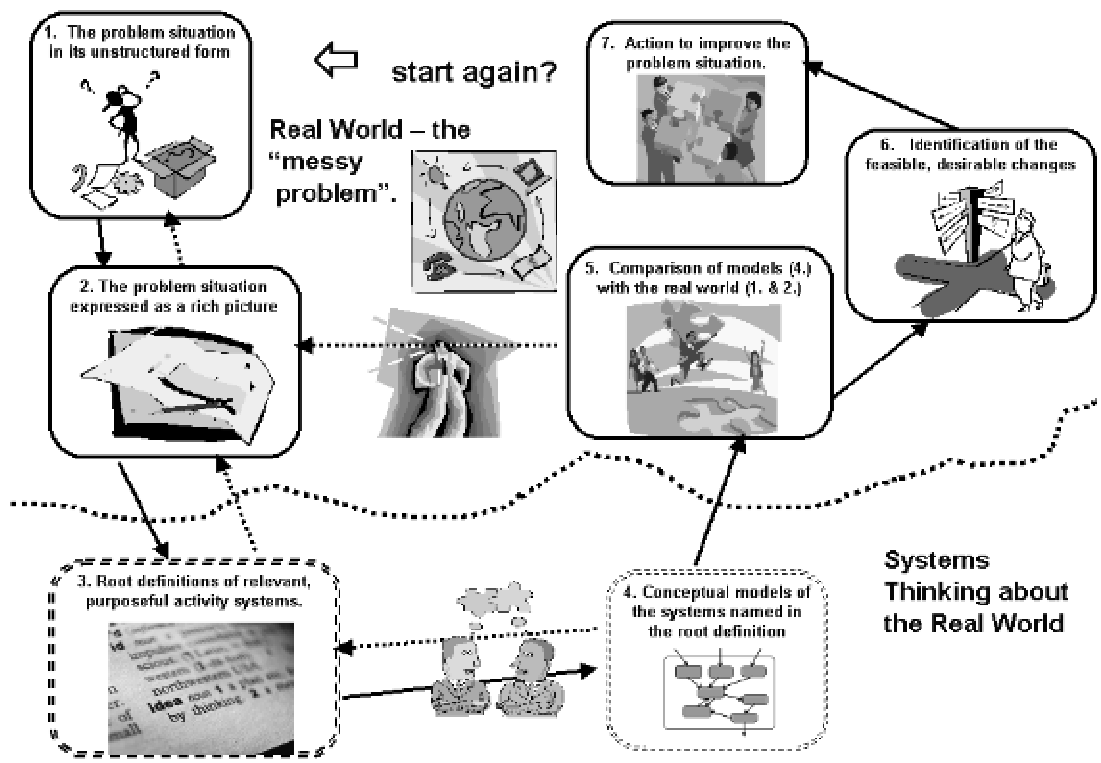


Figure 1. Summary of SSM as a seven-stage process
(Adapted from Checkland, 1999: pp. 163, and Checkland & Scholes, 1990: pp. 28)

Soft Systems Methodology (SSM) may be used to analyse any problem or situation, but it is most appropriate where the problem "cannot be formulated as a search for an efficient means of achieving a defined end; a problem in which ends, goals, purposes are themselves problematic" (Checkland, 1999, p. 316). Soft Systems Methodology, in its idealised form, is described as a logical sequence of seven steps (Checkland, 1999, pp. 162-183). These are illustrated in Figure 2.

It is most important to note that the sequence is not imposed upon the practitioner; a study can commence at any stage, with iteration and backtracking as essential components. SSM encourages investigators to view organisations from a cultural perspective. Therefore the component parts that are human beings determine the essential characteristics of organisations. These "people-components" can attribute meaning to their situation and define their own purpose for the organisation.

Industries with entrenched traditional structures, including the building, construction and engineering industries, are under particular pressure to review their working practices. In this context, Elliman and Orange (2000) recommend SSM as an approach to facilitate effective change and to improve work practice. In particular, SSM is able to stimulate debate and capture the vision for the future of participants. They observe that a soft systems approach allows the exploitation of individual and socially constructed group knowledge and experience. Green (1999) also identifies problems in the building and construction industries and suggests that the potential of SSM lies in the early stages of a project to assist stakeholders to achieve a common understanding of the problem situation. Cushman *et al.* (2002, p.3) observes that "Construction is ultimately a very complex, multi-disciplinary activity and there is a need to integrate the kind of design and management processes in terms of skill and the knowledge that people bring." To achieve this, Cushman *et al.* have used SSM's rich pictures and root definitions to identify responsible actors, key transformations, and the knowledge resources that are appropriate to the needs of a construction company. Venters *et al.* (2002) further describes how SSM can be used to develop conceptual models that identify patterns in knowledge activities. Such patterns can be used to provide a basis for technical design and organisational and social intervention. Based upon the need to address the wicked problems in the construction industry, the following model to apply SSM has been developed (Figure 3) and is being incorporated into investigations into innovation and knowledge management in the construction and building industry.

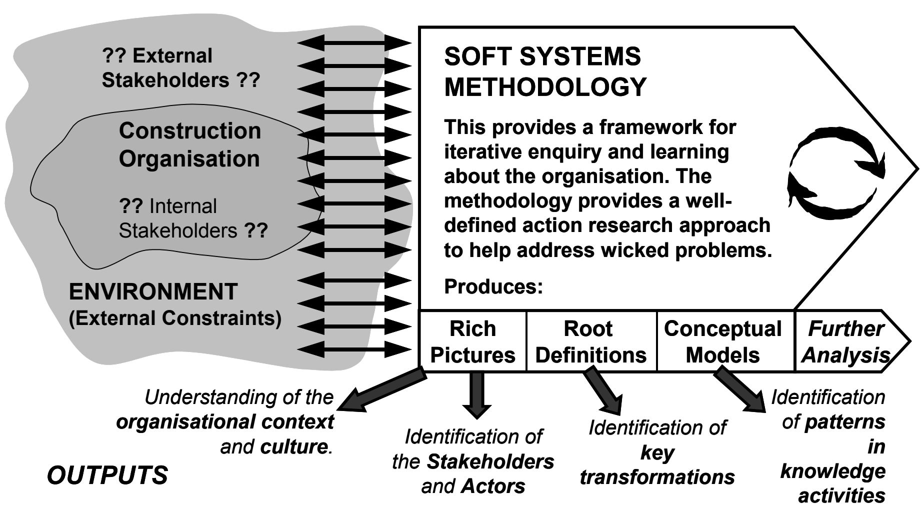


Figure 2. Applying SSM to Knowledge Management in the Construction Industry

3. Five Case Studies

3.1 Pretendering

A major Australian construction contractor company was chosen for the present study. As soft system methodology is helpful for knowledge elicitation in complex and poorly defined areas (Finegan, 1994), a particular organisational process was chosen which was less formal, rather complex and poorly defined. The process selected was "Pre-tendering" - the process by which this organisation makes an early decision to continue, or not, further venturing in a specific project. The pre-tendering approach doesn't exist in an explicit form; rather it depends on the team that informally undertakes it. It is a process that is embedded in the organisation routine and knowledge for carrying out this process mostly resides in the heads of the people in a tacit form. Therefore, pre-tendering presents a good example for illustrating knowledge management implications that are basically concerned with the capture/elicitation, codify, transfer and sharing of embedded, tacit knowledge.

In the case study, the pre-tendering process was usually undertaken by the team, however if an individual team member were to leave the organisation, the loss of tacit knowledge could seriously impact the efficiency of the process. In such circumstances it becomes necessary to make the knowledge involved in the process explicit. Difficulty can arise when attempting to capture related knowledge through a simple flow chart or other illustrating techniques. A flow chart cannot capture the context and does not provide insight into a system that contains interdependent human and technological components. Soft System Methodology serves as an important tool for knowledge elicitation in such circumstances as it aims at understanding the context in which the whole system functions (Finegan, 1994, 1995).

3.1.1 Applying Soft Systems Methodology to the case study

Undertaking the SSM stages as mentioned above, interviews with selected project team members were conducted to develop a rich picture. The objective was to learn about the structures, processes, perceptions and beliefs associated with the case study situation. Developing the rich picture is an iterative process, and to date we have carried out two iterations. The rich picture shown in the Figure 3 and conceptual model shown in Figure 4 represent the work-in-progress at this stage.

In first iteration, interviewees were asked informal, unstructured questions about their involvement in the pre-tendering process based upon their experience and expectations. They were asked to talk about their role and the important tasks that they have performed in the past. It was observed that some participants found it difficult to focus on the answers. This difficulty is normal and can occur when people try to verbalise their tacit thoughts. Therefore an important task of the interviewer was to keep the discussion within the topic and context of the study.

After the interviews, notes taken during the interview were utilised to develop a rich picture. Developing a rich picture is a creative skill and one of the researchers with experience in SSM "work-shopped" the rich picture development in collaboration with other researchers. The rich picture portrayed all the key players involved in the process and presented a structured view by putting into context the factors affecting the process (Figure 3).

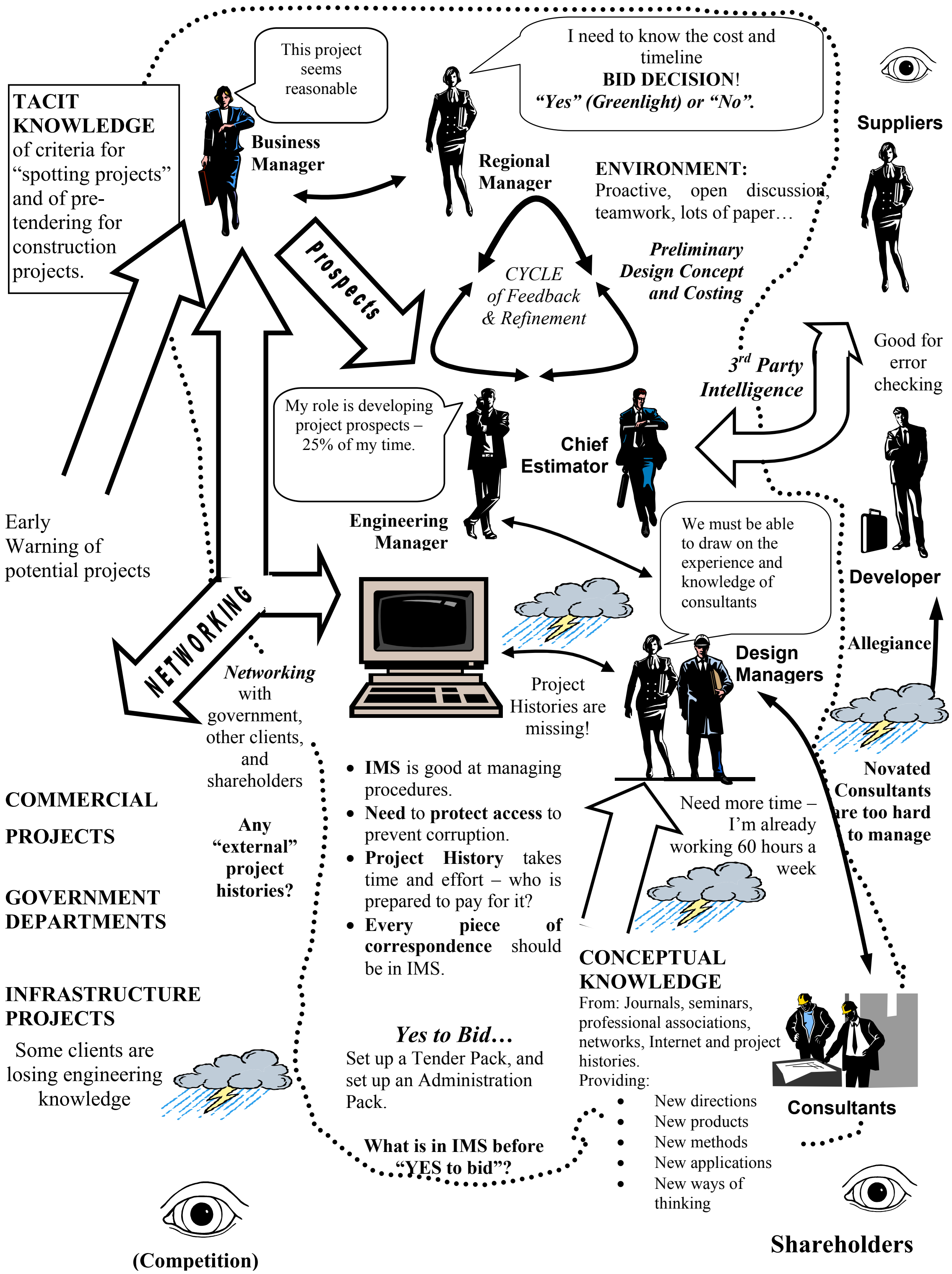


Figure 3: Rich picture Pre-tendering process

ROOT DEFINITION – **Pre-Tendering** A system owned by the pre-contracts team, who together with the Chief Estimator and the Design Managers, takes prospective projects from the Business Manager, together with knowledge, processes and technology, and prepares preliminary understanding of the project and cost estimates. This is used to assist the Regional Manager in assessing the feasibility of making a tender bid. This must be undertaken within short timeframes and with expert assistance from consultants. This is taking place in a very competitive environment where the "fit" to our business objectives and corporate goals, cost and the timeline are all important.	**Customer:** Regional Manager (RM) **Actors:** Engineering Manager, Chief Estimator, Design Manager, Pre-Contracts team, Business Manager. **Transformation:** Knowledge, processes and technology together with details of prospective projects, are used to prepare an understanding of the project and a cost estimate for assessing the feasibility of a tender bid. **Weltanschauung (why Bother?):** To assess the feasibility of making a tender bid, we (RM) need a good understanding of the project – does it fit our corporate objectives - and cost and timeline details. **Owner:** Pre-Contracts Team **Environment:** Competitive, quality, cost and time critical, community and corporate goals.

CONCEPTUAL MODEL – Pre-tendering

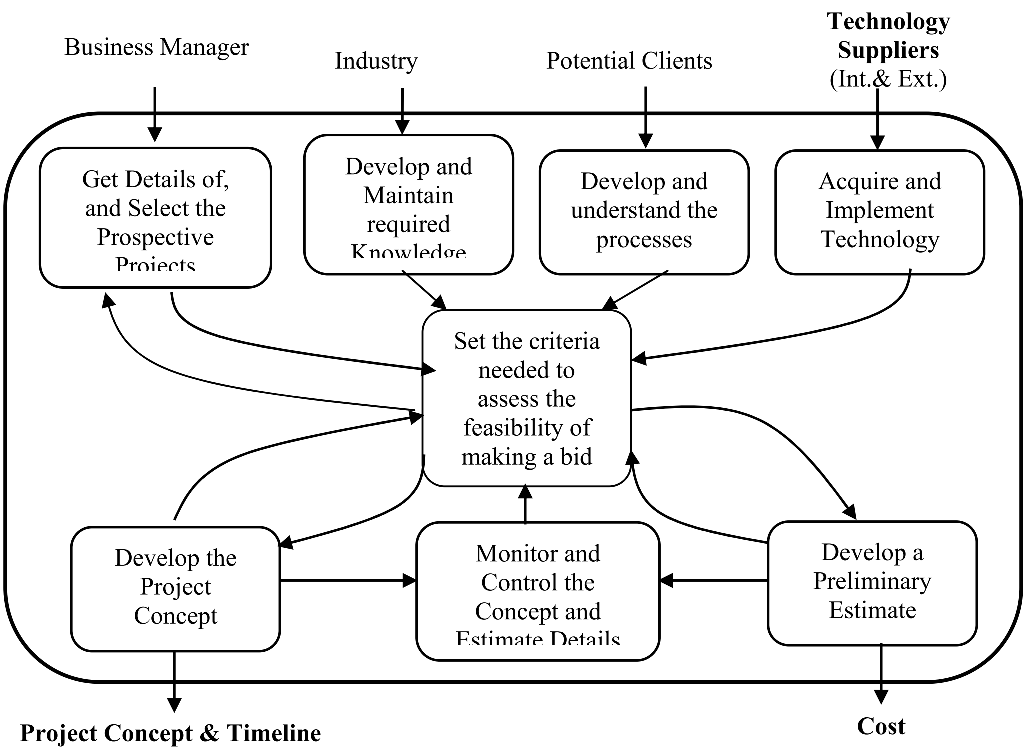


Figure 4: Root Definition, CATWOE and Conceptual Model of Pre-tendering Process.

The root definition, CATWOE and conceptual model were derived from the rich picture, then the initial version of rich picture and model were presented to a focus group of the pre-tendering team members. Participants of focus group, seeing themselves in a picture and interacting with each other were able to elicit further knowledge. One of the participants immediately came up with his own picture of how he interacted with other team members. This facilitated the refinement of the rich picture and conceptual model, and some of the confusion and misunderstanding that resulted from the initial interviews was resolved. With this enhanced understanding, especially of tacit knowledge, the researchers prepared the second iteration of the rich picture and conceptual model.

Figure 3 and Figure 4 shows the rich picture, CATWOE and conceptual model at the end of the second iteration. The research is an on-going and next step is to follow-up with the team members with more structured questions emerging out of the activities identified in the conceptual model and to continue with the SSM approach.

So far what we have accomplished using SSM is significant. The knowledge - which was embedded in the organisation routine and within individuals' beliefs and understandings in tacit form – has been captured and explicitly shown in a form of rich picture without loosing the context. Using SSM has provided us with an approach to help overcome the difficulty in working with tacit knowledge. It has helped to describe and express form to a process, which apparently had no previous formal structure within the organisation. In the words of one of the team members "You have helped formalise the process which has never been done before in our organisation' and "What we are doing here is distilling the facts". SSM not only helped in formalising the knowledge but also elicited areas of conflicts and problems associated with the process.

3.1.2 Knowledge elicited in Pre-tendering process

Key Players in the pre-tendering process were Regional Manager, Business Manager, Engineering Manager, Design Managers, and Chief Estimator. During the process they interact with people external to the organisation like developers, consultants and suppliers. This is illustrated in the rich picture (Figure 3) that shows the structure, processes and especially the beliefs and perceptions of the key players. Also shown are significant relationships, sources of knowledge, and significant concerns and perceived conflicts within the situation.

This rich picture is followed by the development of the root definition that provides the central transformation of the "ideal" pre-tendering system. In this case-study the transformation is defined as: "Knowledge, processes and technology together with details of prospective projects, are used to prepare an understanding of the project and a cost estimate for assessing the feasibility of a tender bid". This transformation is the basis for the development of the conceptual model of pre-tendering (Figure 4). This is expressed as a model of human activity where there are eight high-level key activities necessary to achieve the transformation. Of particular interest as candidates for further study are the three knowledge acquisition activities (or subsystems), the planning subsystem, and the management subsystem:

- Get details of, and select the prospective projects,
- Develop and maintain required knowledge,
- Develop and understand the processes,
- Set the criteria needed to assess the feasibility of making a bid, and
- Monitor and control the concept and estimate details.

The next stage of the research is to interview the participants again with structured questions that will emerge from key activities described by this conceptual model. This detailed information will form the basis of the comparison between the reality of the real world pre-tendering, and the “ideal” expressed by the conceptual model. This comparison – or gap analysis – provides the framework to focus on the issues and opportunities, examine assumptions, and better understand the dysfunctional behaviours/actions that need to be remedied. This stage will also provide a reality check for the analysis to date, and is the point where SSM initiates a process to rethink and re-analyse the underlying assumptions in order to identify the desirable and feasible options for change and improvement in the pre-tendering process. In this case study the complete utilisation of SSM would formalise the knowledge of the pre-tendering process in explicit form, highlight problematic areas and provide recommendations to improve the process.

3.2 Project Histories

3.2.1 Applying Soft Systems Methodology to the case study

The earlier “Pre-tendering” case study provided the basis for undertaking this case study in the same organisation. It strongly emerges that the Pre-tendering team places a very high value on the use of Project Histories so as to prepare a realistic preliminary estimate and concept of the project for which pre-tendering process is being carried out. Nevertheless, the effective use of Project Histories has been plagued with various issues that restrict the Pre-tendering team from effectively utilize them. The research team is of the opinion that it is worthwhile to further investigate the issues barring the effective utilisation of the Project Histories. The same approach as illustrated in previous case study was adopted to develop the Rich Picture (Figure 5), Root Definition and Conceptual Model (Figure 6).

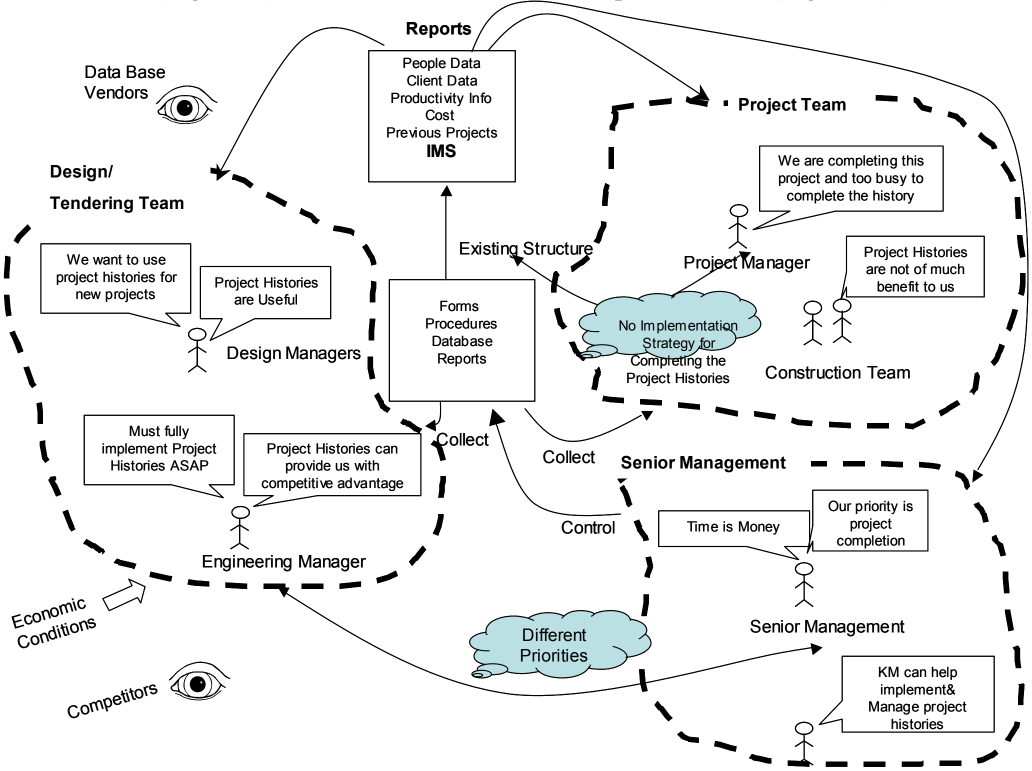


Figure 5: Rich Picture for Project Histories

Root Definition – Project Histories	**Customer:** Senior Management, Future Design Managers, Project Managers
A system owned by the Engineering Manager, who together with the Design Managers, seek data, information and knowledge from previous projects stored in project histories in order to prepare realistic preliminary understanding of the project and cost estimates for pre-tendering process and then for preparing the project bids.	**Actors:** Engineering Manager, Design Managers, Project Managers, Construction Team **Transformation:** Knowledge, processes and technology together with details of past projects, are used to create and maintain a repository of a project histories that can be used when preparing a tender bid for a new project. **Weltanschauung (why bother?) :** To assess the feasibility of making a tender bid, a good understanding of the project is required based upon previous organisation experience and knowledge. **Owner:** Engineering Manager **Environment:** Competitive, Quality, Cost and time critical, Community and Corporate Goals.

Conceptual Model – Project Histories

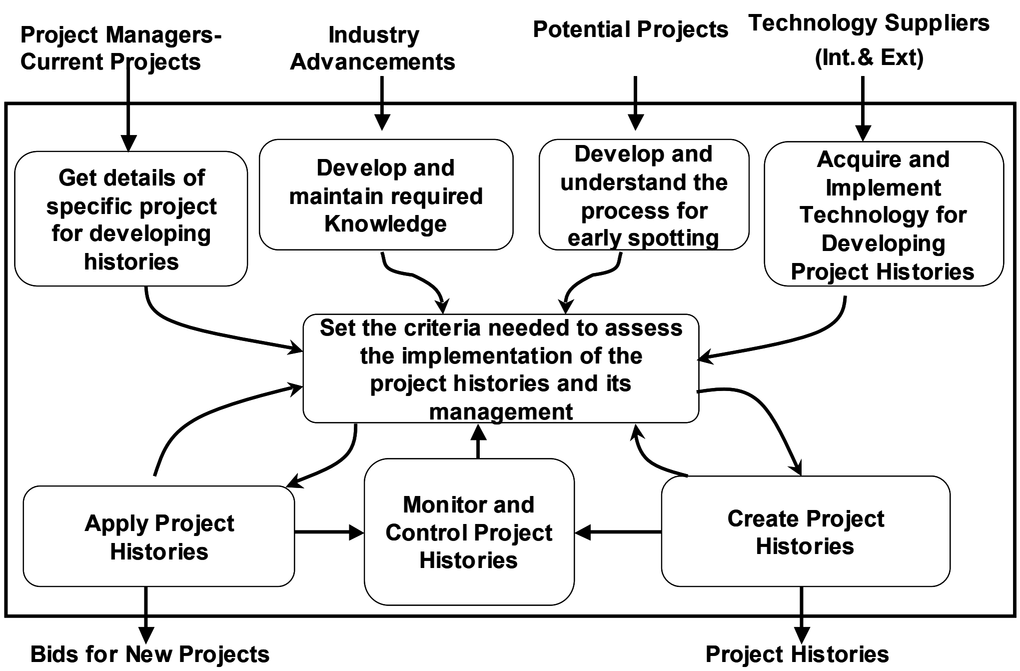


Figure 6: Root Definition, CATWOE and Conceptual Model of Project Histories

3.2.2 Knowledge elicited about Project Histories

Project Histories are basically the repositories/data bases that are developed to contain useful information and knowledge from the previous projects. In the organisation under study, the information, like productivity rates on previous projects, cost and timelines, and client details, mainly form the part of these repositories. These project histories are operated through an organisational ICT (Information and Communication Technology) system referred to as IMS (Information Management System). As one of the leading contractors company in Australia, the organisation under study has championed the use of ICT (since mid 1990's) as part of its commitment to become a Best-in-Practice organisation. IMS has become the general and most usual form of communication in the organisation and successfully been diffused with in the organisation even to the foreman level. Whereas IMS is effectively utilized while the project is in progress, it is rarely used to successfully develop and maintain a history when the project is finished.

Developing a history requires the sifting through of huge volumes of information generated while project is being executed, and identifying and sorting the information that may be of use on next projects. Though in project close-out procedures, project debriefing about the project just finished is done, it is often not sufficient to provide and record the useful information for future use. The lack of interest of the project team in participating in project debriefing further aggravates the problem and eventually, there is very little that is carried forward from a previous project to be used in future projects. Hence, most of the knowledge carried from one project to other remains "Tacit" – residing as knowledge of individuals. The success of project histories proliferation alone is highly unlikely, unless it is seen as a part of the some strategic and business philosophy like Knowledge Management.

The benefits that project histories can deliver are significant and very clear in the minds of the people who want to use them. However, as shown in the Rich Picture (Figure 5) this small group of people is less likely to influence the other functioning team members who have different priorities. As illustrated by the activities defined in the Conceptual Model (Figure 6) Knowledge Management places a great emphasis upon the project histories and see it as a mechanism whereby not only useful information is assorted and stored but efforts are made to turn "Tacit" knowledge of the individuals into "Explicit" and is disseminated to all others through these repositories. These repositories, then, contain lessons learnt, unique problem handling techniques devised by the individual when faced with problem on the project, etc so as to stop "Re-inventing the wheel" on the next project thus saving time and resources. Attaching the context of Knowledge Management to the scenario of project histories will give these histories a new vigour and framework for understanding by both senior management and the project team.

3.3 Bridge Project

3.3.1 Applying Soft Systems Methodology to the case study

After conducting the case study on "Project Histories", it was deemed necessary to further look for the cases that can successfully become part of the project histories and the lessons generated in those projects can be the effectively used in improving pre-tendering process on future projects. This case study documents the commonly observed scenario while tendering, where multiple parties try hard to bid on a certain project and only one with the lowest bid achieves success. This case study documents a tendering process on a Bridge Project where the bidder lost their bid by a very small margin. It was claimed by the bidder that with a little more expense, the client was going to get a lot more value out of the design. However, by disregarding value analysis and resorting to competitive bidding, the bid with the lowest price (with less value) was selected.

The case study, illustrated in the Rich Picture (Figure 7) also illustrates the difficulty that tendering team experienced throughout the tendering process due to the very short time available for preparing the bid, then to discover that they had failed to be successful by a very small margin. In this case, client had undertaken an investigation of the site in the previous 3 to 4 years, but had not completed a final design. It then became a task of the bidder to develop a realistic design in addition to the cost and time estimate that would form a bid within the short time span of 12 weeks. The routine method of bridge design and the typical construction method could not be used because of the nature of soil (clay) that was very difficult to compact. Also, the presence of wild life sanctuary in the vicinity of the bridge made the design and construction environmentally sensitive and subject to community interest. To achieve a suitable solution all the team worked strenuously and developed a realistic design, cost and timeline, and bid was submitted. The bid was eventually lost by a very little margin, much to the disgust of the bidding team and especially the design manager. The project team shared the experience gained in developing this bid, adding to their tacit knowledge. By applying SSM, this experience has been made explicit and is documented in the Rich Picture (Figure 7), and Root Definition and Conceptual Model in Figure 8.

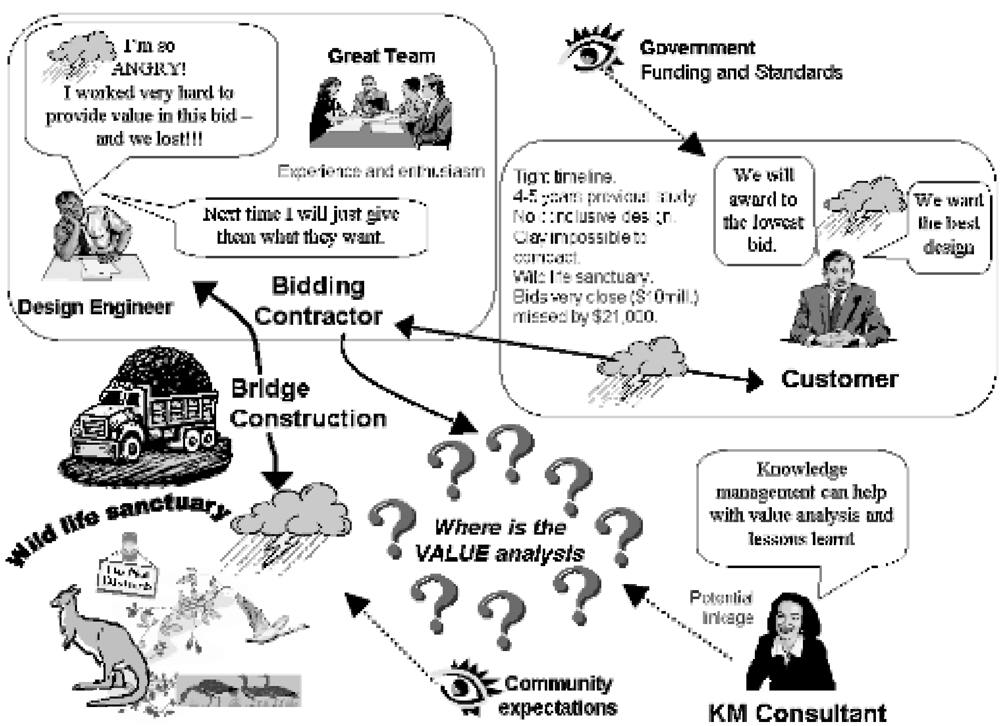


Figure 7: Rich Picture of the Bridge Project

ROOT DEFINITION – Bridge Project A system owned by the Bidding Contractor, who together with the Design Engineer, use knowledge, skills and experience to prepare competitive bids for the design and construction of bridge projects. This is undertaken with the understanding that while the client wants a low price, there is also a desire to obtain the best value in a bid. These bids must also take into consideration the competitive market and community expectations for the design and construction of a major project.	**Customer:** The client and the community **Actors:** Bidding contractor, competitors, design engineer, design team, client. **Transformation:** To use knowledge, skills and experience to prepare competitive bids for the design and construction of bridge projects. **Weltanschauung (why Bother?):** While the client wants a low price, there is also a desire to obtain the best value in a bid. **Owner:** Bidding Contractor **Environment:** Competitive, quality, cost and time critical, and community expectations.

CONCEPTUAL MODEL – THE BRIDGE PROJECT

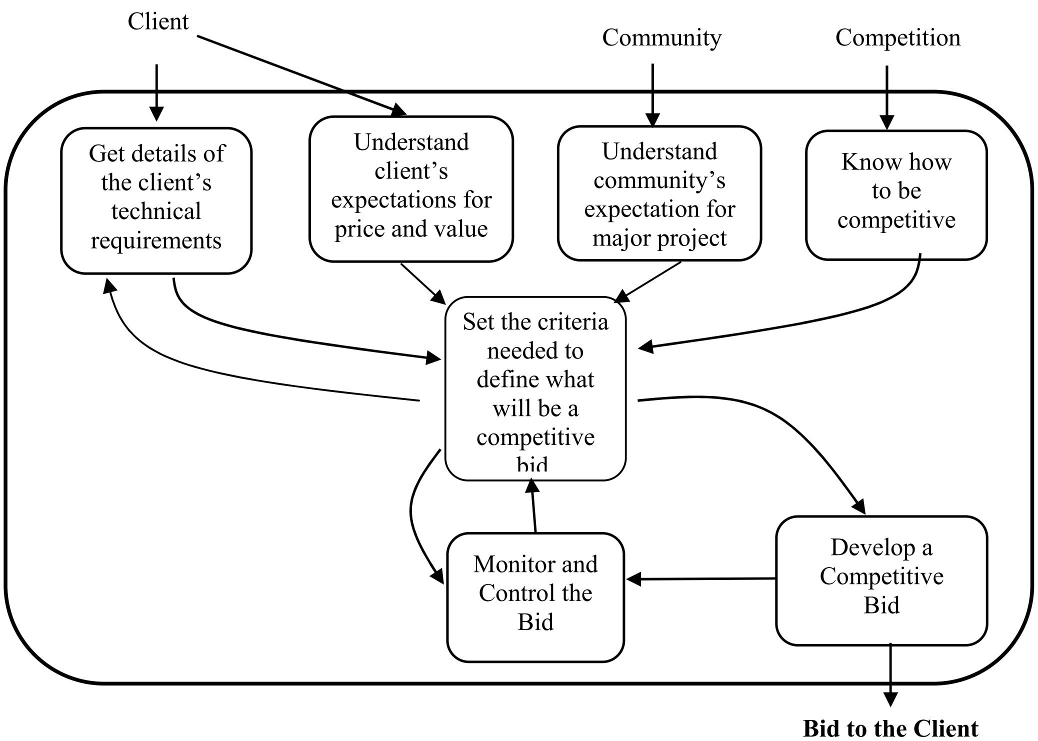


Figure 8: Root Definition, CATWOE and Conceptual Model of the Bridge Project.

3.3.2 Knowledge elicited about the Bridge Project.

The case study elicited various kinds of knowledge. For example, the deficiencies on the part of the client who were not able to complete a design of their own after 3-4 years of the study of the project. Also, that the value analysis was disregarded, allowing the client to select the lowest bid that offered comparatively lesser value in comparison with the second lowest bid.

This strengthens the case for devising a criteria based not solely on the lowest quoted price, but also on the value that a bid provides. This issue of value management is an important topic of ongoing research in construction practice.

The case study also documents how the design manager learnt the lesson by working very hard on a project, and then failing to get a bid. He then promised himself not to work so hard in terms of providing value while making bid for future projects. As in his own words “Next time I will give them what they want”, echoes the fact that he would not be performing innovatively on the future projects and would rather stick to the conventional approach. This reality goes against the vision of the construction industry, which looks forward to becoming innovative and modernised to get rid of notoriously low productivity levels. In terms of knowledge management, by documenting and disseminating the knowledge and lessons learnt in this case study, it is possible to improve the bidding on the future projects.

3.4 Road Project

3.4.1 Applying Soft Systems Methodology to the case study

This case study documents the process of tendering/bidding on a road project where it was required to construct the culverts to manage the flow of water. The rich picture in Figure 9 describes the problematic situation. Flood modelling was the basis for the selection of size and spacing of the culverts and this aspect was mostly covered in this case study. The design and construction method itself were of routine nature and were not investigated.

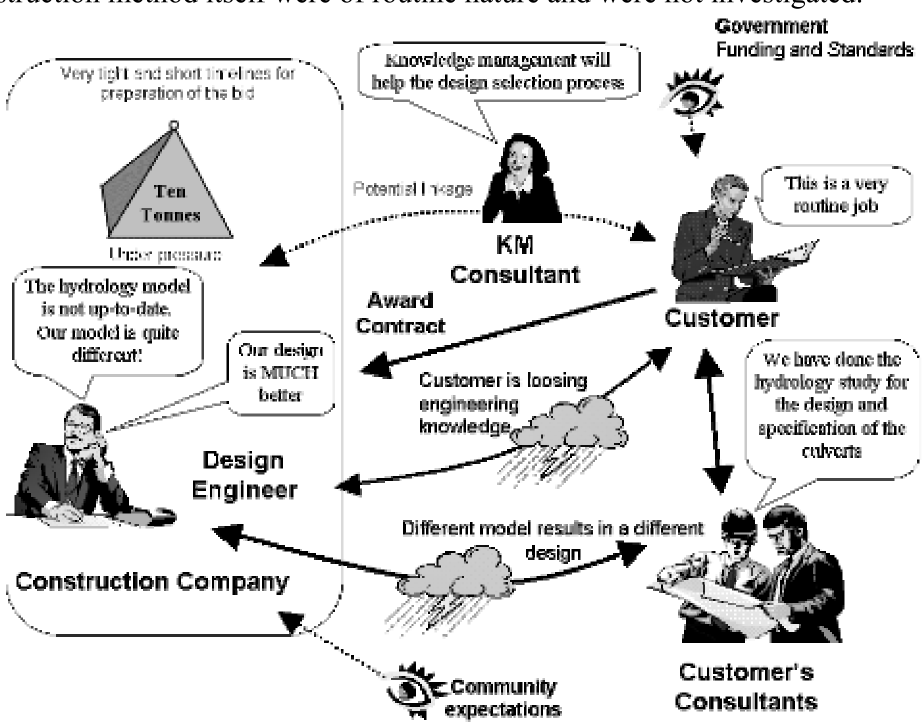


Figure 9: Rich Picture of the Road Project

ROOT DEFINITION – ROAD PROJECT A system owned by the Construction Company, who together with the Design Engineer, use knowledge, skills and experience to prepare competitive designs that delivers the most appropriate solution for the project. This is undertaken where the client may be loosing engineering knowledge and the client's consultants have not provided the optimal design parameters. These bids must also take into consideration the competitive market and community expectations for the design and construction of a major project.	**Customer:** The client and the community **Actors:** Construction company, design engineer, client, client's consultants. **Transformation:** To use knowledge, skills and experience to prepare competitive designs that delivers the most appropriate solution for the project. **Weltanschauung (why Bother?):** the client may be loosing engineering knowledge and the client's consultants have not provided the optimal design parameters. **Owner:** Construction Company **Environment:** Competitive, quality, cost and time critical, and community expectations.

CONCEPTUAL MODEL – THE ROAD PROJECT

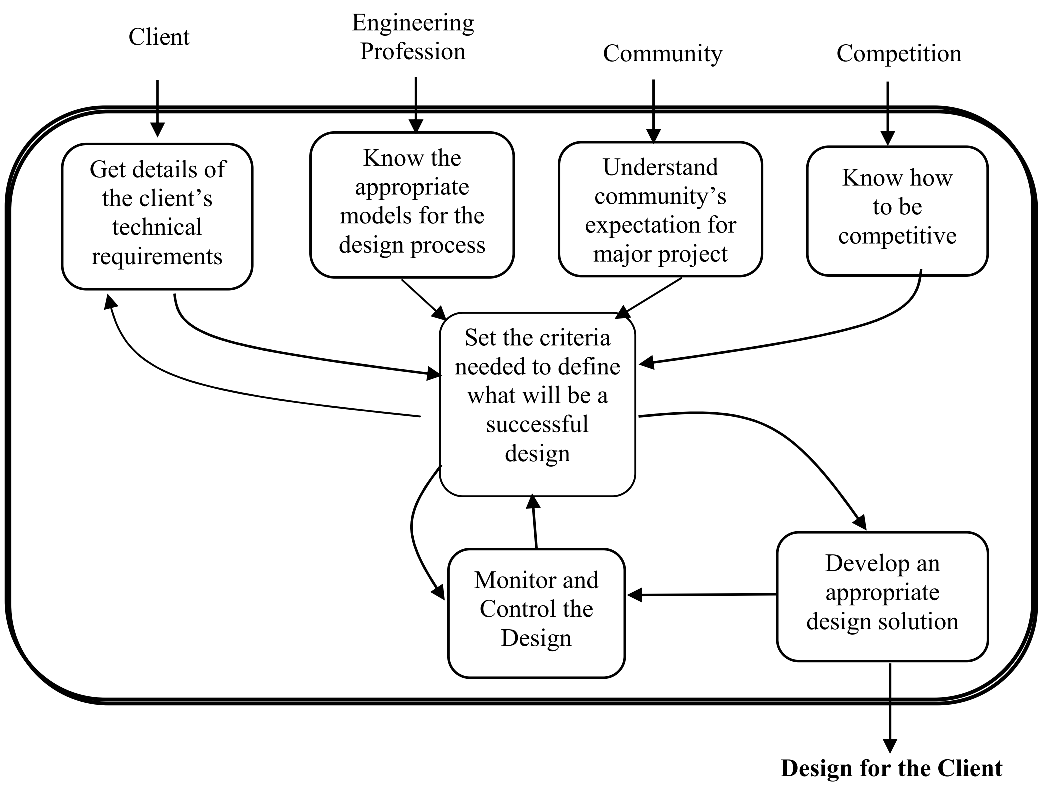


Figure 10: Root Definition, CATWOE and Conceptual Model of the Road Project.

3.4.2 Knowledge elicited about the Road Project.

Client has carried out the hydrological study of the area almost five years ago and based on their subsequent flood modelling they allocated the space and sizing of the culverts and hence initiated a bid process. The organization under study was one of the bidders and didn't agree with the sizing and spacing of the culverts as provided by the client. The bidding organization carried out their own flood modelling and challenged the client's specification for culverts based on the new model and the design properties derived from it. They completed their study under severe time pressure and were able to convince the client of their sizing and spacing, and eventually produced significant cost savings on the whole project. Figure 10 describes the Root Definitions and Conceptual Model for this case study. The knowledge gained in this process can significantly help the pre-tendering process. It explains in a explicit fashion that client may not be right all the time and sometimes it is worthwhile to explore alternative options. That the client is loosing the engineering knowledge is an important insight achieved by the bidding organization. From client's point of view, the explicit fact is that they need to strengthen their technical base.

3.4 BAMTEC innovation diffusion case study

The case study specifically describes the adoption and diffusion process of an innovative product called "Bamtec" in the organization under study. The technical nature of the product is immaterial to the execution of this case study. The most important issue is to know that the process behind the proliferation of such an innovation in the organization so as to know how it was adopted and diffused. Issues like adoption of innovation and its diffusion are central to the core of knowledge management. Knowledge Management helps in spotting such innovation that have the potential to improve the productivity and then provides a framework to adopt and diffuse that innovation through out the organization in order to reap benefits from that innovation.

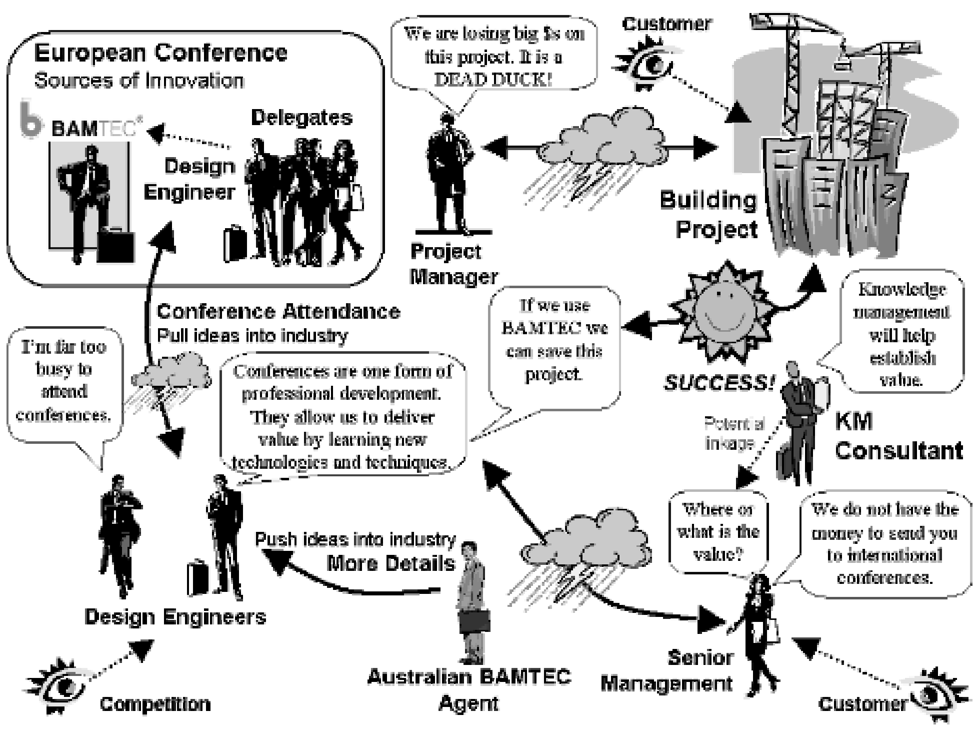


Figure 11: Rich Picture of the BAMTEC study

ROOT DEFINITION – BAMTEC A system owned by the Design Engineers, who with the support of Senior Management are able to achieve professional development and learn new ideas and techniques by attending major, international conferences. This adoption of innovative building techniques can be the key to project success. However, Senior Management need to be convinced of the value of conference attendance, and many design engineers consider themselves to be too busy to attend conferences.	**Customer:** The building company, project managers, the clients and the community. **Actors:** Design engineer, senior management. **Transformation:** To achieve professional development and learn new ideas and techniques by attending major, international conferences. **Weltanschauung (why Bother?):** This adoption of innovative building techniques can be the key to project success. **Owner:** Design engineer **Environment:** Work pressure, cost and time critical, and community expectations.

CONCEPTUAL MODEL – THE BAMTEC PROJECT

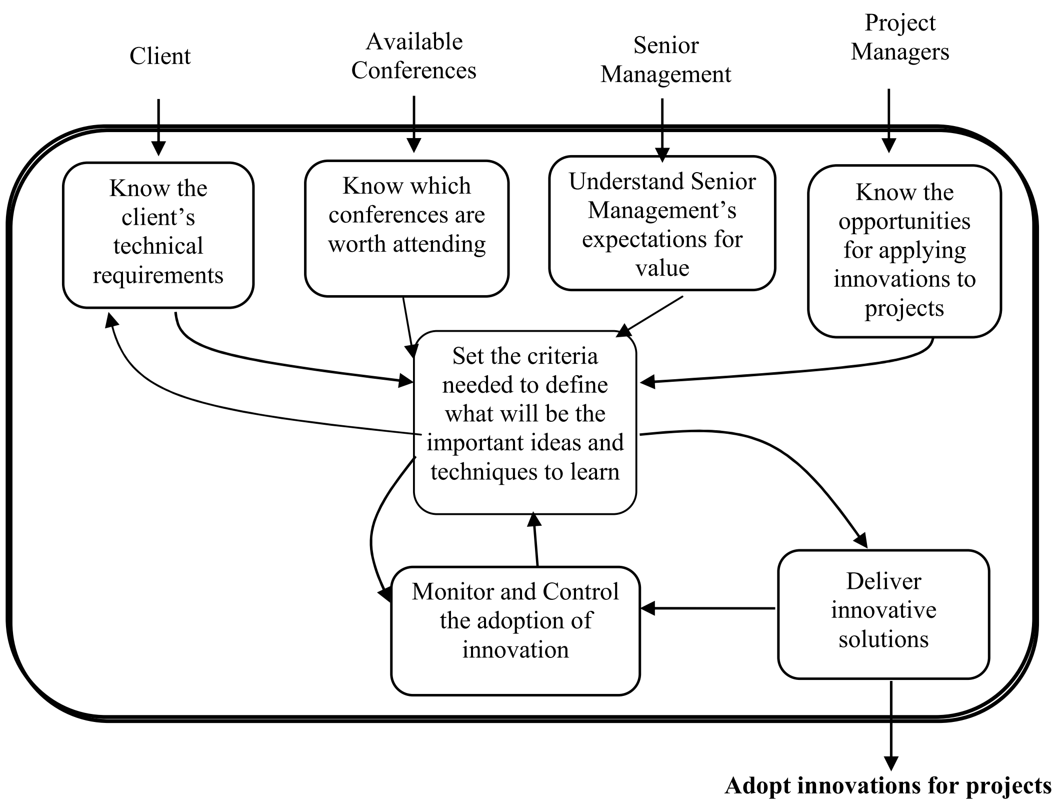


Figure 12: Root Definition, CATWOE and Conceptual Model of the BAMTEC study.

The rich picture in Figure 11 highlights a pictorial representation of the related processes. The innovative product under study was displayed at a European construction conference. This conference was attended by one of the design managers from the organization under study. The rich picture documents the values and beliefs usually existing in the organization. For some, attending conferences is not an important deal but some others take it seriously and have expectations that their organization to allow them attend such events on a regular basis. In this case, design manager implemented the use of the BAMTEC product in a project that previously had been declared as a "dead duck". It was the sort of the project that was running over budget but not returning any profit to the organization. Implementing the BAMTEC product on the project - in the words of the design managers - "literally" saved the project and pushed it towards a profitable outcome. Knowledge Management may help make these events happen on regular basis. The root definition and conceptual model shown in Figure 12 give an explicit description of how a specific innovation can be adopted and diffused and can be effectively utilized for the benefit of the organization.

4. Conclusions And Further Work

This paper has illustrated the approach of applying SSM to problems in construction project management, especially those knowledge management problems that are challenging to understand and difficult to act upon. It includes five case studies of its use in dealing with the confusing situations that incorporate human, organizational and technical aspects. SSM encourages group learning and is ideal as a group decision-making approach. It is strengthened by the active participation by different participants and stakeholders, and encourages joint ownership of the problem solving process. Finally, SSM is recommended where an organisation is seeking to achieve changes in workplace culture and transformation into a learning organisation.

5. References

Andrews, C.L. (2000). "Restoring legitimacy to the systems approach," *IEEE Technology and Society.* 19 (4), 38-44.

Ballard, G. (2002). "Managing work flow on design projects: a case study." *Engineering, Construction and Architectural Management*. Vol. 9, No. 3, 284-291.

Barry, M. and Fourie McIntosh, C. (2001). "Wicked problems, soft systems and cadastral systems in periods of uncertainty". *Proceedings of CONSAS,* Cape Town, South Africa, 12-14 March, 2001, 7 pages.

Barthorpe, S., Duncan, R. and Miller, C. (2000). "The pluralistic facets of culture and its impact on construction", *Property Management,* 18 (5), 335-351.

Becker, F. (2002). "Organisational dilemmas and workplace solutions". *Journal of Corporate Real Estate*, Vol 4, No. 2, 129-149.

Bresnen, M. and Marshall, N. (2001). "Building Partnerships: Case Studies of Client-Contractor Collaboration in the UK Construction Industry", *Construction Management and Economics,* 18(7), 819-832.

Bryson, J.M., Cunningham, G.L. & Lokkesmoe, K.J. (2002). "What to do when stakeholders matter: The case of problem formulation for the African American men project of Hennepin County, Minnesota". *Public Administration Review,* Vol. 62, No. 5, 568-584.

Buckingham Shum, S. (1997). "Representing Hard-to-Formalise, Contextualised, Multidisciplinary, Organisational Knowledge". *AAAI Spring Symposium on Artificial Intelligence in Knowledge Management,* Stanford University, Palo Alto, CA, Mar. 24-26, 1997, 12 pages.

Checkland, P.B. & Scholes, J. (1990) Soft Systems Methodology in Action. Chichester: John Wiley & Sons.

Checkland, P.B. (1999). *Systems Thinking, Systems Practice.* Chichester: John Wiley & Sons.

Cushman, M., Venters, W., Cornford, T. and Mitev, N. (2002). “Understanding sustainability as knowledge practice”. Presented to *British Academy of Management Conference: Fast-Tracking Performance through Partnerships*, London, UK, September 9-11, 6 pages.

Department of Environment, Trade and the Regions, (1998). *Rethinking Construction,* Report. London.

Department of Industry Science Resources, (1999). *Building for Growth – An Analysis of the Australian Building and Construction Industries,* Canberra, Australia, National Building and Construction Committee (NatBACC) for the Government of Australia**:** 88.

Elliman, T. and Orange, G. (2000). “Electronic commerce to support construction design and supply-chain management: a research note”. *International Journal of Physical Distribution and Logistics Management*, Vol. 30, No. 3/4, 345-360.

Gann, D. (2001). “Putting academic ideas into practice: technological progress and the absorptive capacity of construction organizations”, *Construction Management and Economics,* 19, 321-330.

Green, S.D. (1999). "A participative research strategy for propagating soft methodologies in value mangement practice." *Construction Management and Economics*. Vol. 17, No. 3, 329-340.

Gustafsson, C. (2002). “From concept to norm - an explorative study of office design management from an organizational perspective”. *Facilities,* Vol. 20, No. 13, 423-431.

Lang, J.C. (2001a). “Managerial concerns in knowledge management”. *Journal of Knowledge Management,* Vol. 5, No. 1, 43-57.

Lang, J.C. (2001b), “Managing in knowledge-based competition”. *Journal of Organizational Change Management,* Vol. 14, No. 6, 539-553.

Latham, M. (1994). *Constructing the Team, Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry.* London: HMSO.London.

Lingard, H. and Sublet A., (2002). “The impact of job and organizational demands on marital or relationship satisfaction and construction among Australian civil engineers”, *Construction Management and Economics,* 20, 507–521

Oglesby, C. H., Parker, H. W., and Howell G. A., (1989). *Productivity Improvement in Construction,* U.S.A.: McGraw-Hill.

Rittel, H.J., and Webber, M.M. (1984). "Planning Problems are Wicked Problems." In N.Cross (Ed.), *Developments in Design Methodology*. Chichester, UK: John Wiley & Sons, 135-144.

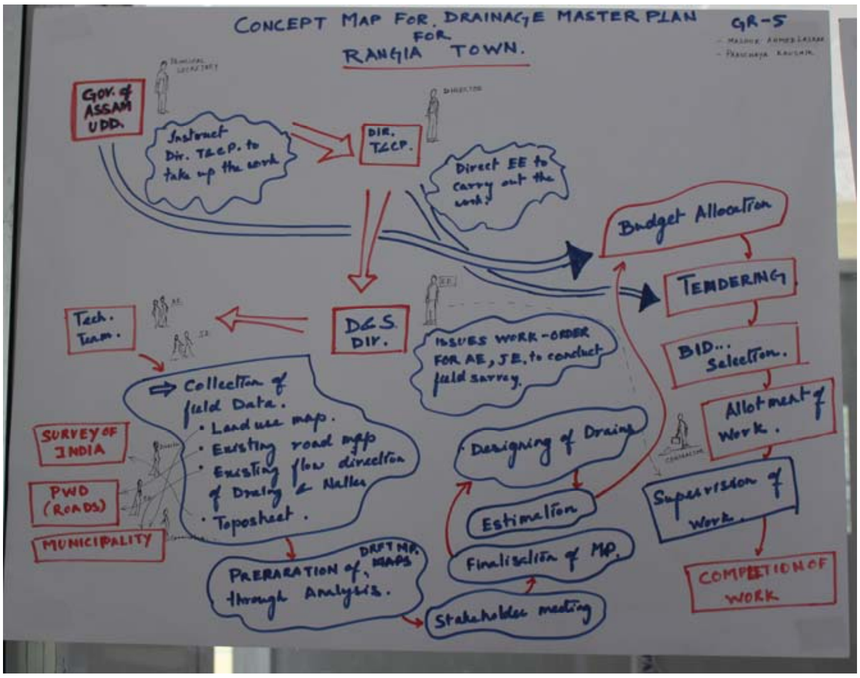
Santos, A. dos., Powell, A. F., and Sarshar, M. (2002). “Evolution of management theory: the case of production management in construction”, *Management Decision,* 40(8), 788-796.

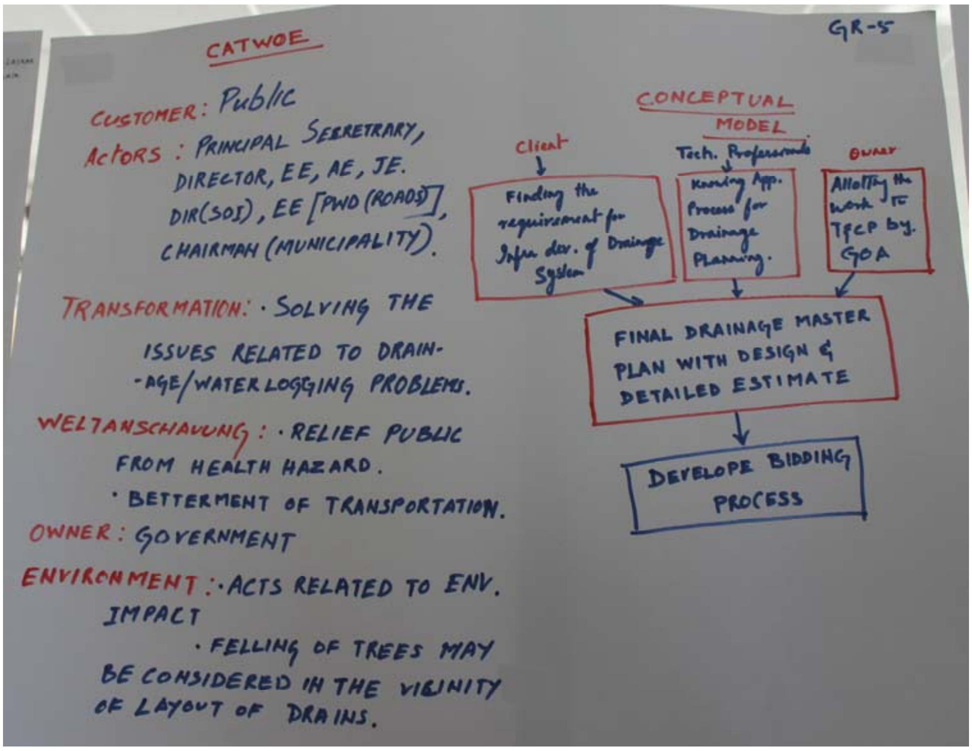
Savage, G.T., Nix, T.W., Whitehead, C.J. and Blair, J.D. (1991). “Strategies for assessing and managing organizational stakeholders”. *Academy of Management Executive,* Vol. 5, No. 2, 61-75.

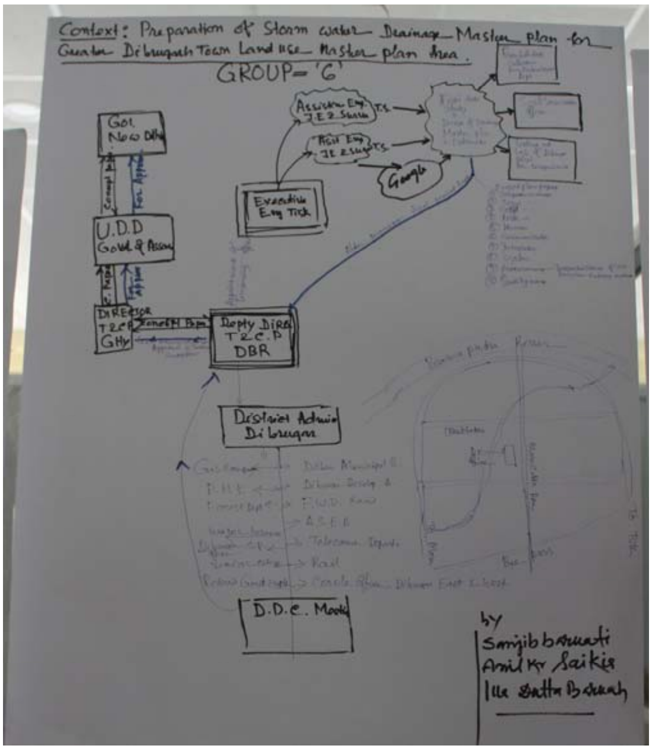
Venters, W., Cushman, M. and Cornford, T. (2002). “Creating Knowledge for Sustainability: Using SSM for Describing Knowledge Environments and Conceptualising Technological Interventions”, *Organisational Knowledge Learning and Competencies Conference,* Athens, April 2002, 11 pages.

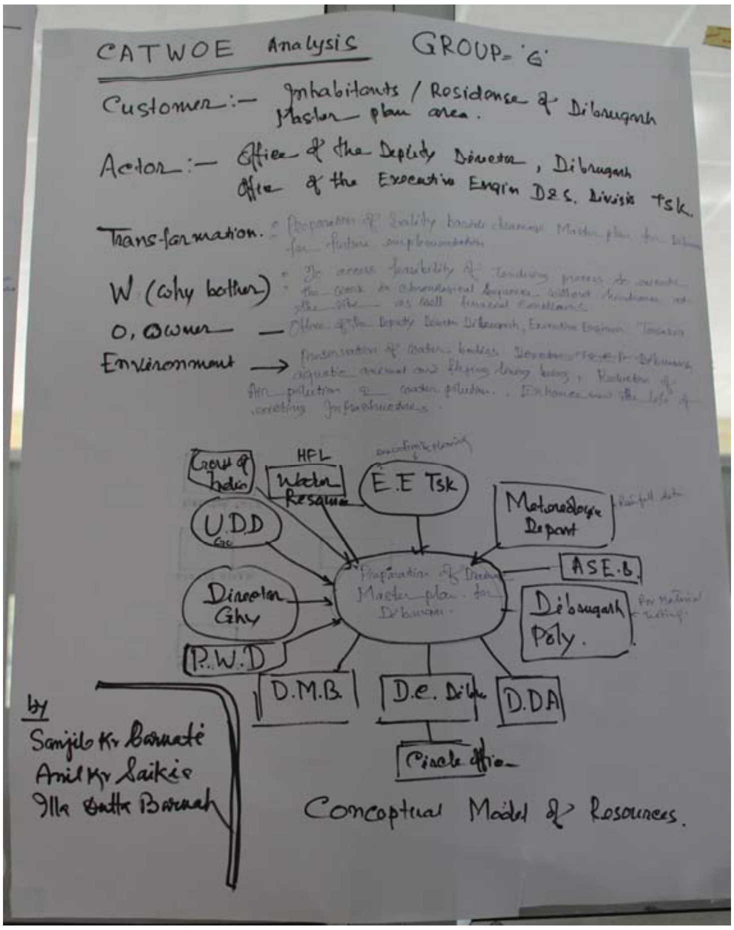
Vickers, G. (1968). *Value Systems and Social Process.* London, Penguin Books.

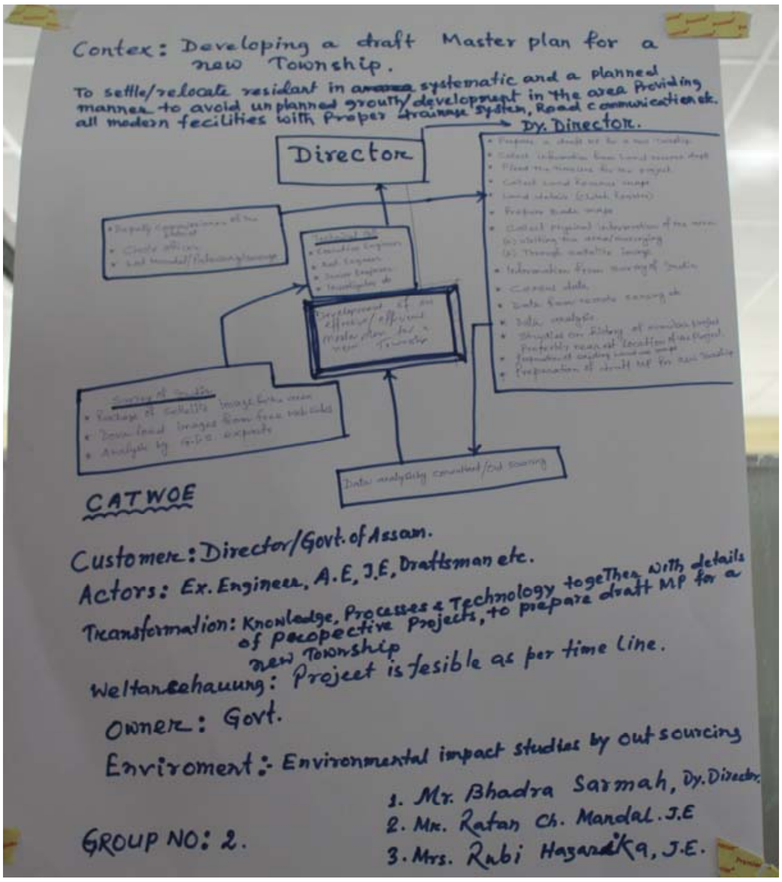
Application of SSM in the real case project - demonstrated by the participants from Town & Count Planning Department, Assam


CONCEPT MAP FOR DRAINAGE MASTER PLAN FOR RANGIA TOWN.
GR-5
GOV. of ASSAM UDD.
Instruct Dir. T&CP. to take up the work
DIR. T&CP.
Direct EE to carry out the work
Budget Allocation
TENDERING
BID... Selection.
Allotment of work.
Supervision of work.
COMPLETION OF WORK
D&S. Dir.
Issues work-order for AE, JE, to conduct field survey.
Tech. Team.
Collection of field Data.
· Land use map.
· Existing road map
· Existing flow direction of Drains & Nallas
· Toposheet.
SURVEY OF INDIA
PWD (ROADS)
MUNICIPALITY
PREPARATION of DRFT MP, MAPS through Analysis.
Stakeholder meeting
Finalisation of MP.
Estimation
Designing of Drains


CATWOE
GR-5
CUSTOMER: Public
Actors: PRINCIPAL SECRETRARY, DIRECTOR, EE, AE, JE. DIR(SOI), EE [PWD (ROADS)], CHAIRMAN (MUNICIPALITY).
TRANSFORMATION: · SOLVING THE ISSUES RELATED TO DRAIN-AGE/WATER LOGGING PROBLEMS.
WELTANSCHAUUNG: · RELIEF PUBLIC FROM HEALTH HAZARD.
· BETTERMENT OF TRANSPORTATION.
OWNER: GOVERNMENT
ENVIRONMENT: · ACTS RELATED TO ENV. IMPACT
· FELLING OF TREES MAY BE CONSIDERED IN THE VICINITY OF LAYOUT OF DRAINS.
CONCEPTUAL MODEL
Client
Finding the requirement for Infra dev. of Drainage System
Tech. Professionals
Knowing App. Process for Drainage Planning.
Owner
Allotting the work to T&CP by GOA
FINAL DRAINAGE MASTER PLAN WITH DESIGN & DETAILED ESTIMATE
DEVELOPE BIDDING PROCESS


Context: Preparation of Storm water Drainage Master plan for Greater Dibrugarh Town Land Use Master plan Area.
GROUP='G'
GOI New Delhi
U.D.D Govt of Assam
DIRECTOR T&CP GHY
Depty DIRE T&C.P DBR
Executive Eng Tsk
Google
District Admin Dibrugarh
by
Sanjib Baruah
Anil Kr Saikia
Ila Dutta Baruah

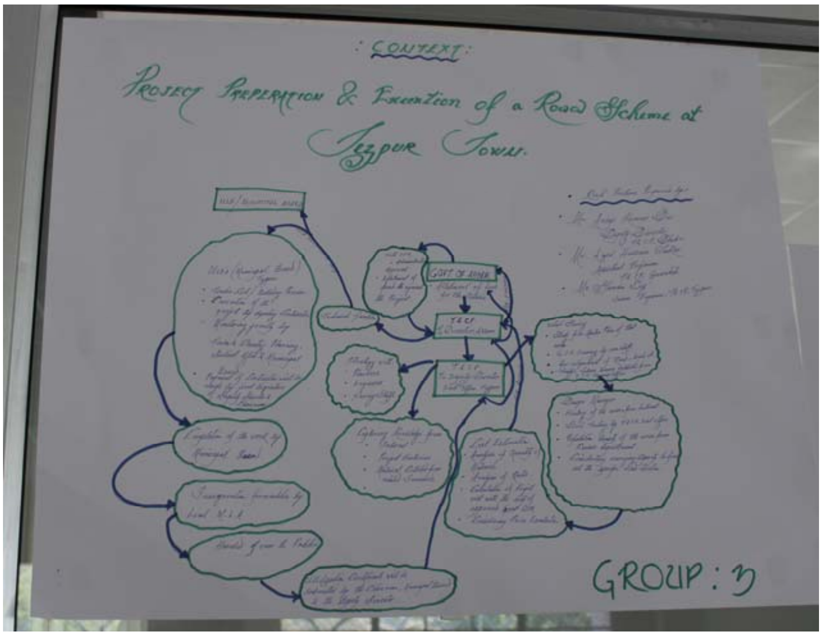

CATWOE Analysis GROUP='G'
Customer:- Inhabitants / Residence of Dibrugarh Master plan area.
Actor:- Office of the Deputy Director, Dibrugarh
Office of the Executive Engin D&S. Divisio Tsk.
Trans-formation.
W (why bother)
O, Owner
Environment
HFL
Water Resource
E.E Tsk
U.D.D
Meteorology Depart
ASE.B
Director Ghy
Dibrugarh Poly.
P.W.D
D.M.B.
D.DA
Circle office
by
Sanjib Kr Baruah
Anil Kr Saikia
Ila Dutta Baruah
Conceptual Model of Resources.

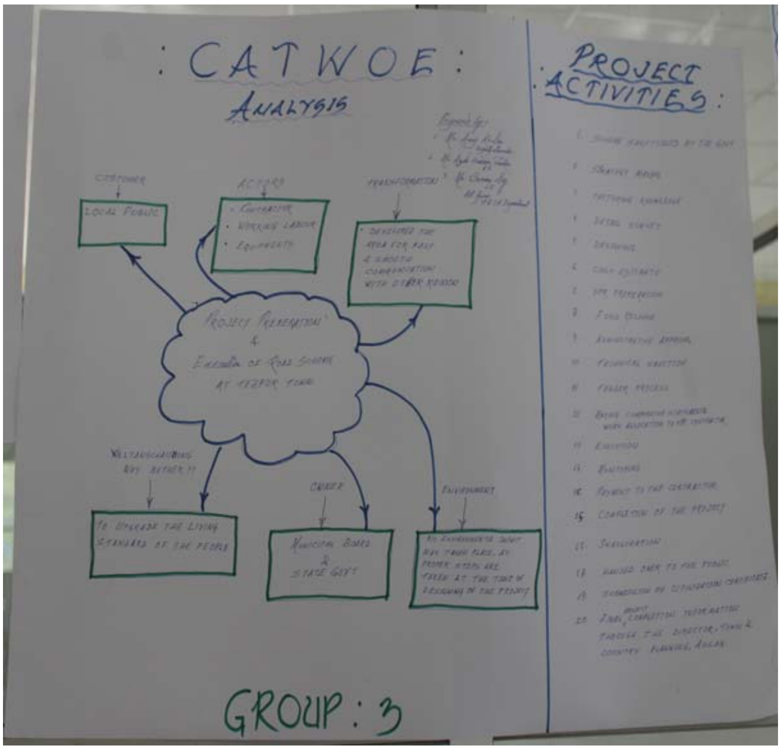


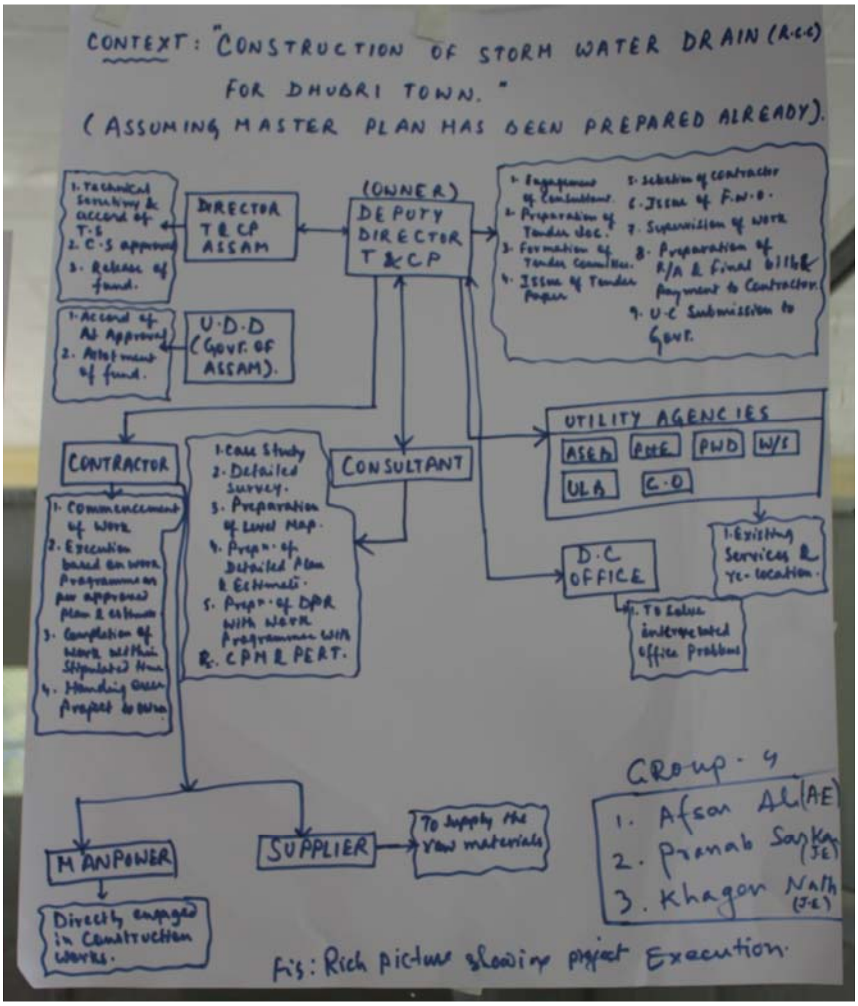
Contex: Developing a draft Master plan for a new Township.
To settle/relocate residant in ~~a~~ systematic and a planned manner to avoid unplanned grouth/development in the area Providing all modern fecilities with proper drainage system, Road communication etc.
Dy. Director.
Director
CATWOE
Customer: Director/Govt. of Assam.
Actors: Ex. Engineer, A.E, J.E, Draftsman etc.
Transformation: Knowledge, Processes & Technology together with details of perspective Projects, to prepare draft MP for a new Township
Weltanschauung: Project is fesible as per time line.
Owner: Govt.
Enviroment:- Environmental impact studies by out sourcing
1. Mr. Bhadra Sarmah, Dy. Director
2. Mr. Ratan Ch. Mandal. J.E
3. Mrs. Rubi Hazarika, J.E.
GROUP NO: 2.

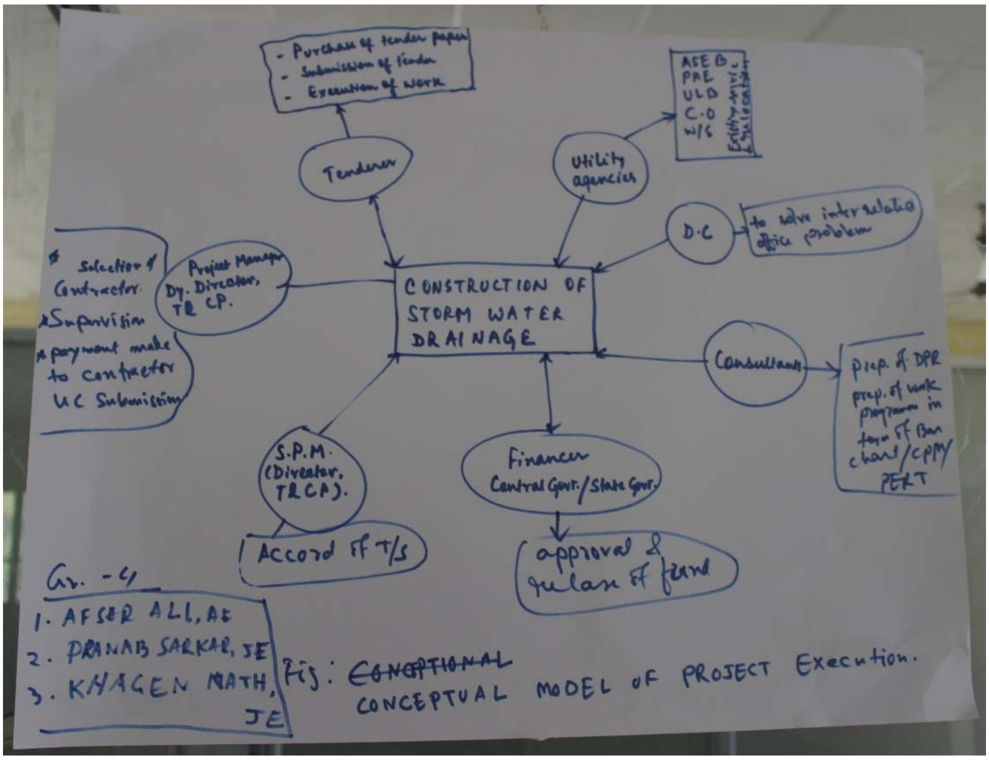

CONTEXT: PREPETARY STAGE FOR A DRAINAGE PROJECT/MASTER PLAN FOR A SMALL URBAN AREA.
RICH DIAGRAM
GROUP NO 1


CATWOE Analysis
GR NO-1
CONCEPTUAL PLAN
COMMUNITY
DATA COLLECTION
SURVEY
HISTORY
ANALYSIS & DESIGN
ESTIMATION
TIME PLAN
PUBLIC CONSULTATION
Feed back.

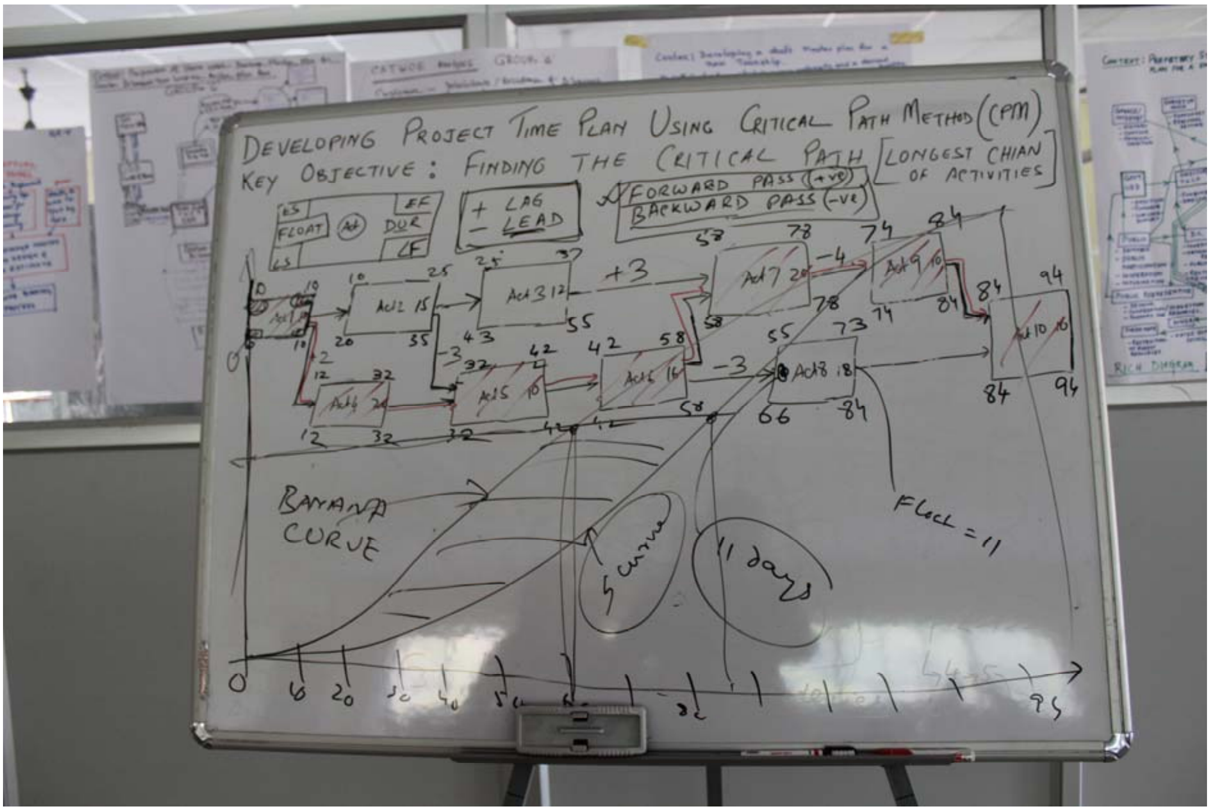

CONTEXT
Project Preperation & Execution of a Road Scheme at Tezpur Town.
GIFT OF MONEY
GROUP : 3

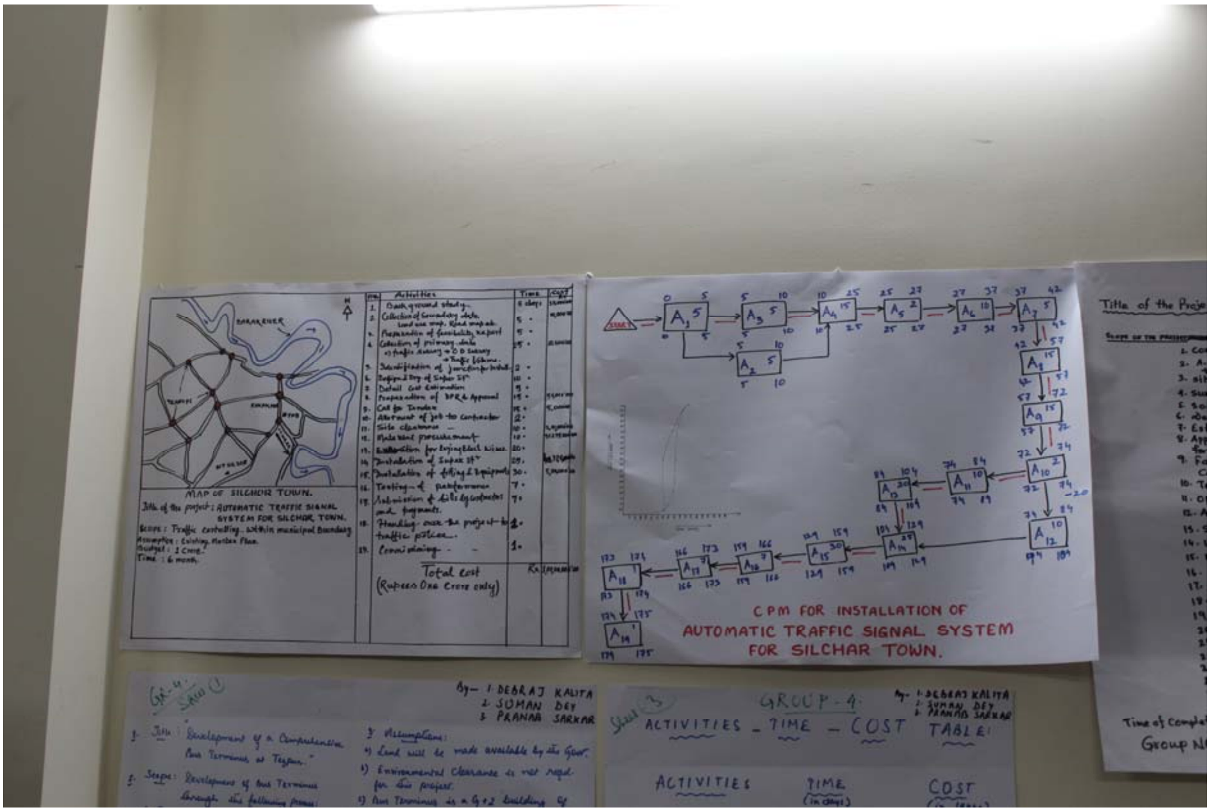

: CATWOE :
ANALYSIS
CUSTOMER
LOCAL PUBLIC
ACTORS
TRANSFORMATION
ENVIRONMENT
PROJECT ACTIVITIES :
GROUP : 3

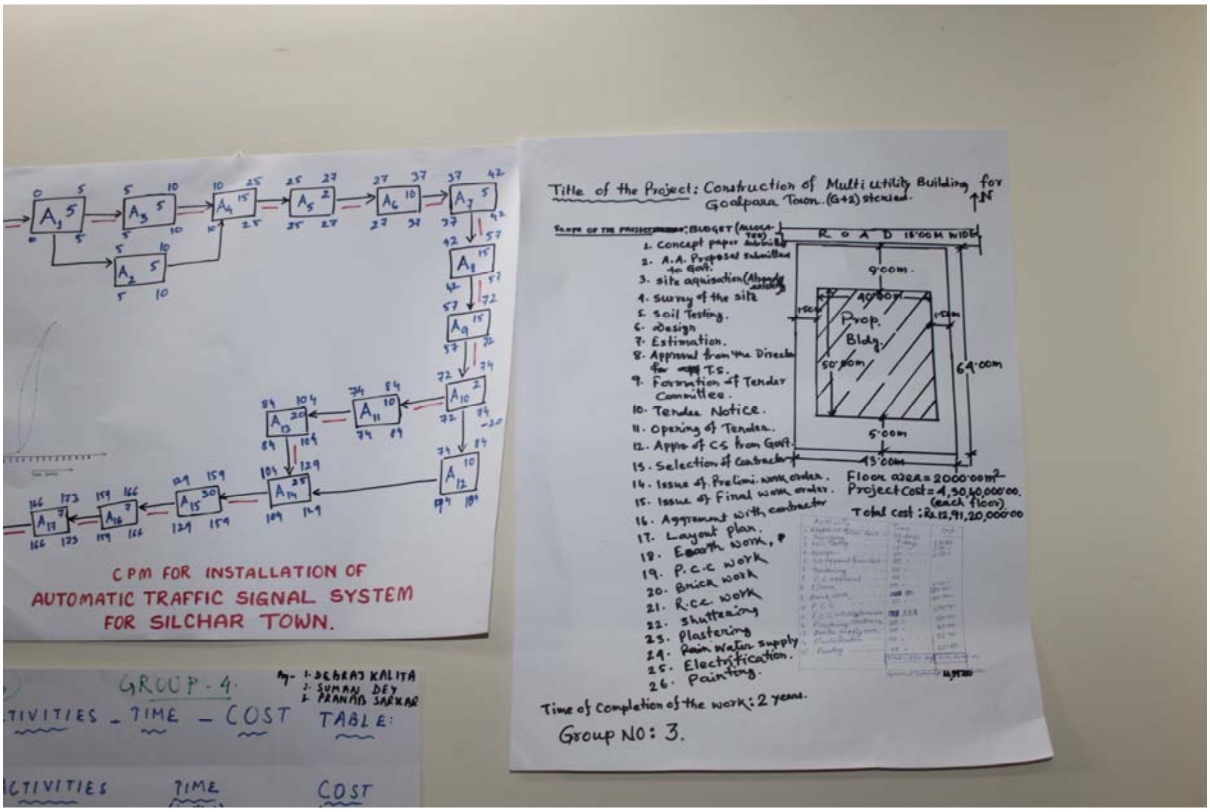

CONTEXT: "CONSTRUCTION OF STORM WATER DRAIN (R.C.C) FOR DHUBRI TOWN."
(ASSUMING MASTER PLAN HAS BEEN PREPARED ALREADY).
(OWNER) DEPUTY DIRECTOR T&CP
DIRECTOR T&CP ASSAM
U.D.D (GOVT. OF ASSAM).
CONTRACTOR
CONSULTANT
UTILITY AGENCIES
ASEB PHE PWD W/S ULB C.O
D.C OFFICE
MANPOWER
SUPPLIER
To supply the raw materials
Directly engaged in construction works.
GROUP - 4
1. Afsar Ali (AE)
2. Pranab Sarkar (JE)
3. Khagen Nath (J.E)
Fig: Rich picture showing project Execution.

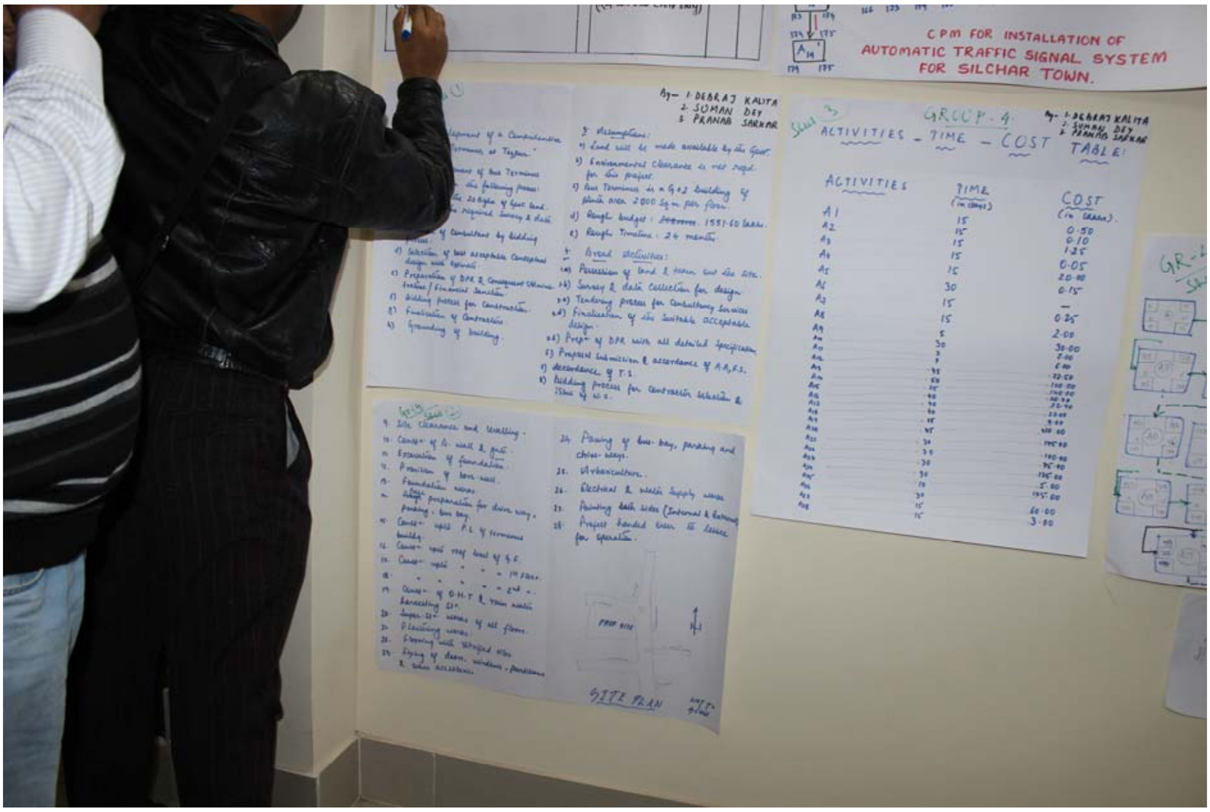

CONSTRUCTION OF STORM WATER DRAINAGE
Tenderer
- Purchase of tender paper
- Submission of tender
- Execution of work
Utility agencies
ASEB PHE ULB C.O W/S
D.C
to solve inter related office problem
Project Manager Dy. Director, T& CP.
Consultants
Financer Central Govt./State Govt.
approval & release of fund
S.P.M. (Director, T&CP).
Accord of T/S
Gr. - 4
1. AFSER ALI, AE
2. PRANAB SARKAR, JE
3. KHAGEN NATH, JE
Fig: CONCEPTUAL MODEL OF PROJECT Execution.

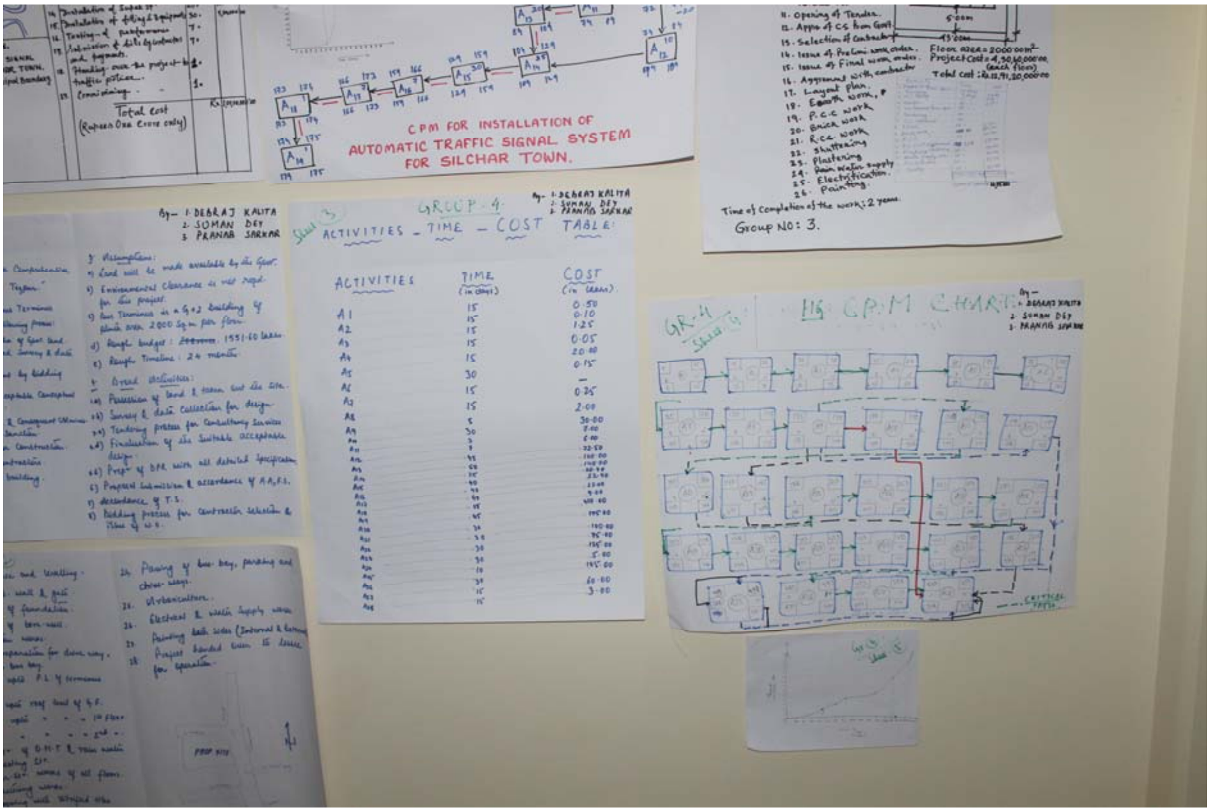
- Project planning
- Activity identification and dependency mapping
- Schedule development
- Cashflow analysis

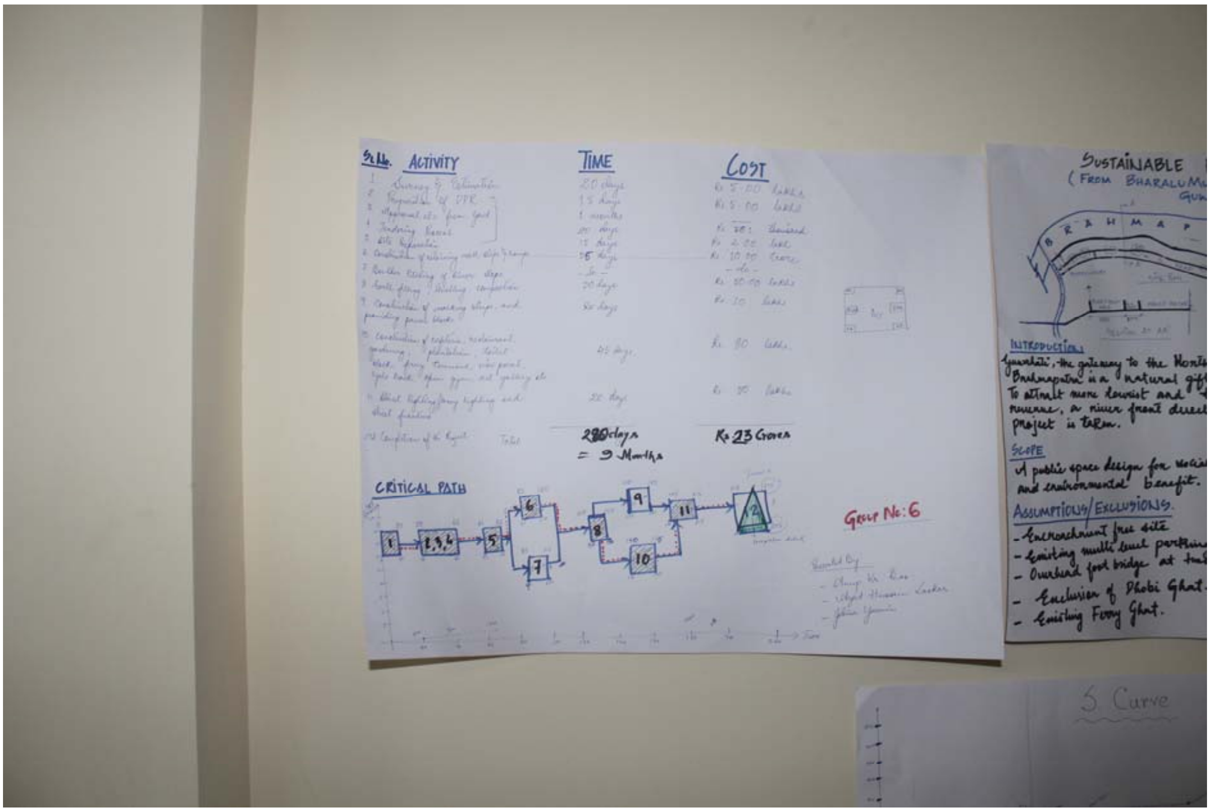

DEVELOPING PROJECT TIME PLAN USING CRITICAL PATH METHOD (CPM)
KEY OBJECTIVE : FINDING THE CRITICAL PATH [LONGEST CHIAN OF ACTIVITIES]
FORWARD PASS (+ve)
BACKWARD PASS (-ve)
+ LAG
- LEAD
BANANA CURVE
11 days

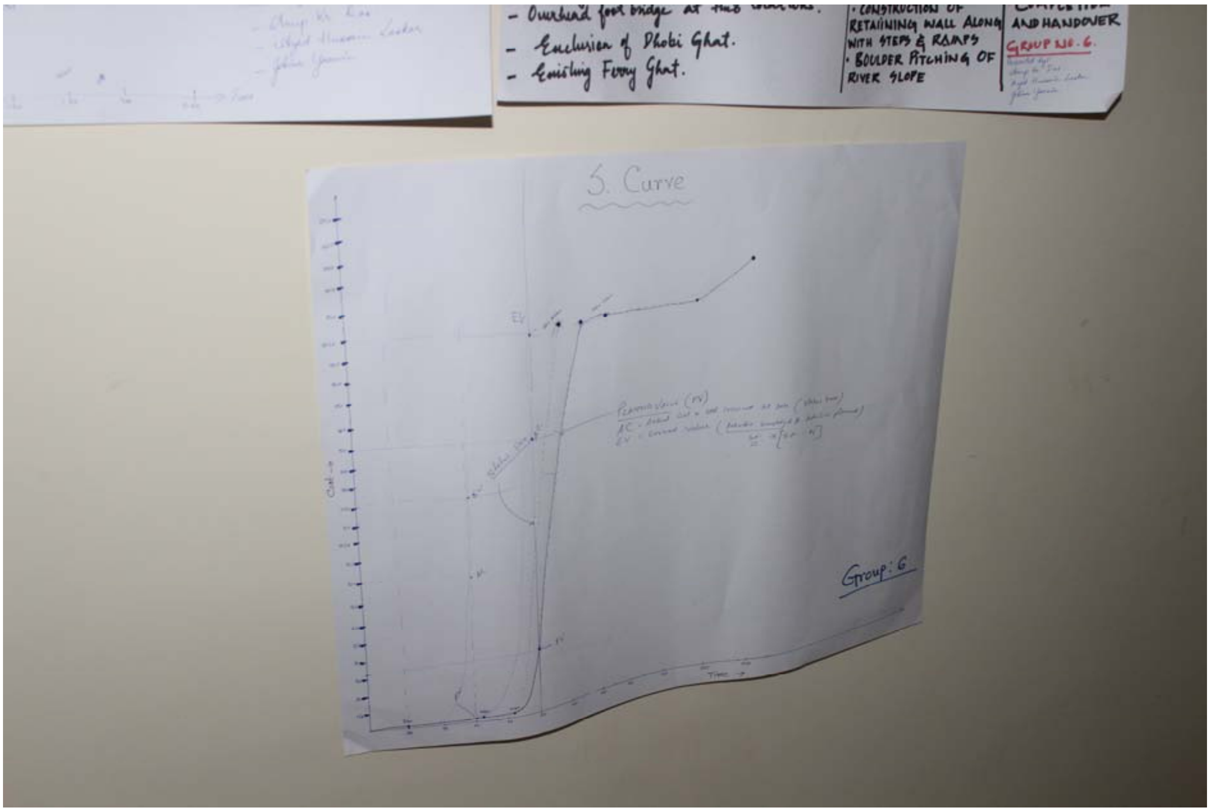

MAP OF SILCHAR TOWN.
Total cost
(Rupees One Crore only)
CPM FOR INSTALLATION OF
AUTOMATIC TRAFFIC SIGNAL SYSTEM
FOR SILCHAR TOWN.
GROUP - 4
ACTIVITIES - TIME - COST TABLE
ACTIVITIES
TIME
COST


CPM FOR INSTALLATION OF
AUTOMATIC TRAFFIC SIGNAL SYSTEM
FOR SILCHAR TOWN.
GROUP - 4
ACTIVITIES - TIME - COST TABLE:
Title of the Project: Construction of Multi utility Building for Goalpara Town. (G+2) storied.
Time of Completion of the work: 2 years.
Group NO: 3.

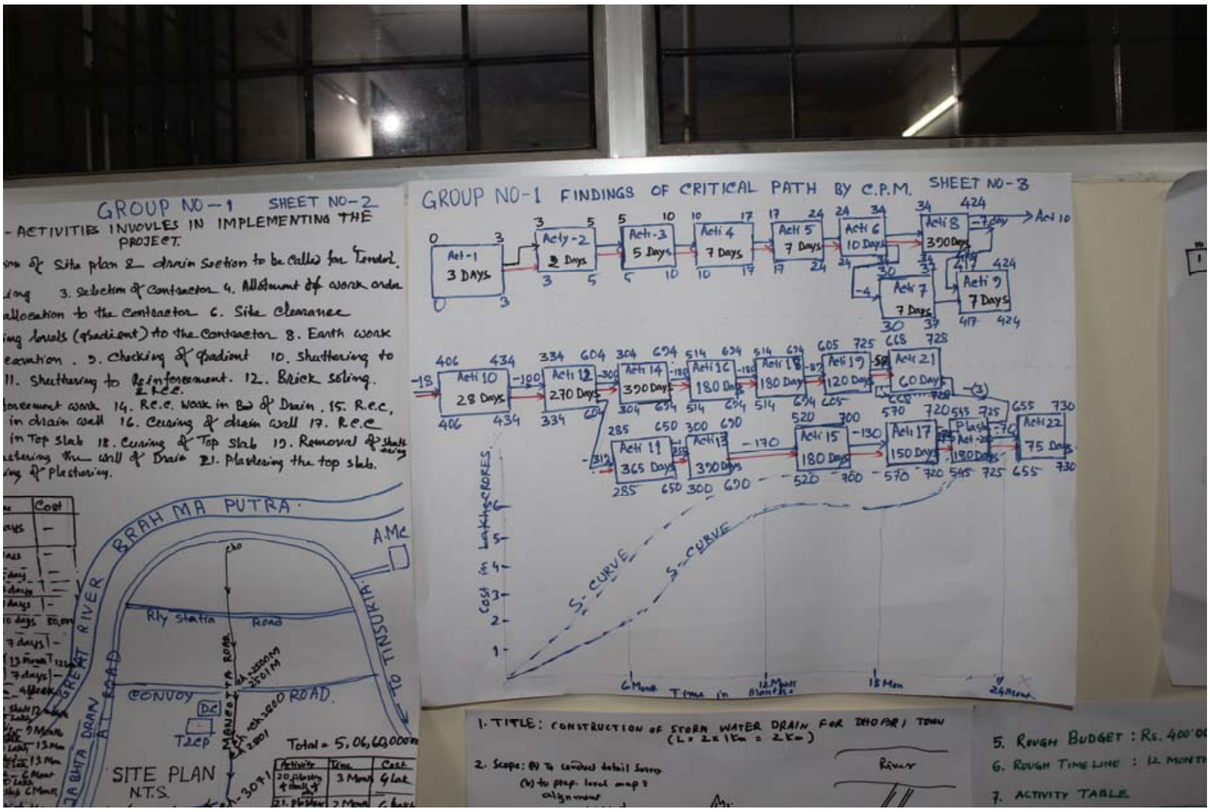

CPM FOR INSTALLATION OF
AUTOMATIC TRAFFIC SIGNAL SYSTEM
FOR SILCHAR TOWN.
GROUP - 4
ACTIVITIES - TIME - COST TABLE:
ACTIVITIES
TIME
COST
SITE PLAN

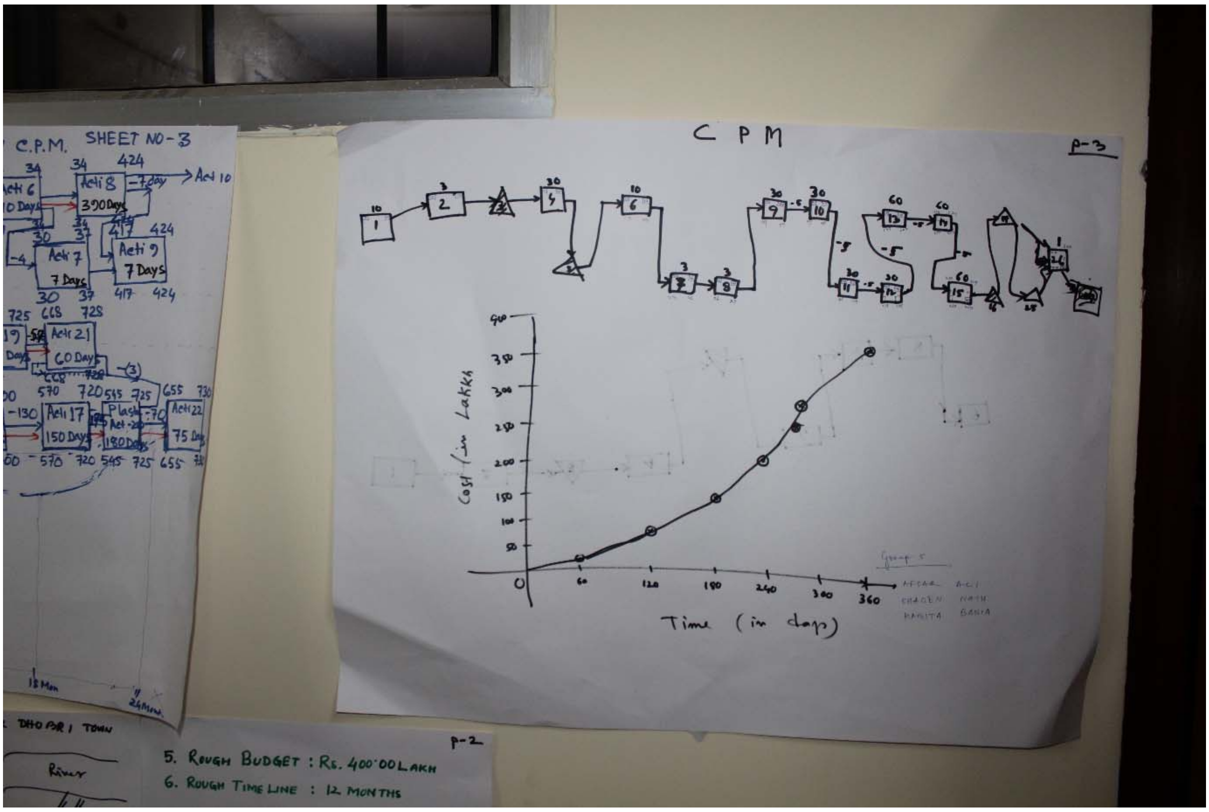

CPM FOR INSTALLATION OF
AUTOMATIC TRAFFIC SIGNAL SYSTEM
FOR SILCHAR TOWN.
GROUP-4
ACTIVITIES - TIME - COST TABLE
ACTIVITIES
TIME
COST
C.P.M CHART
Group NO: 3.

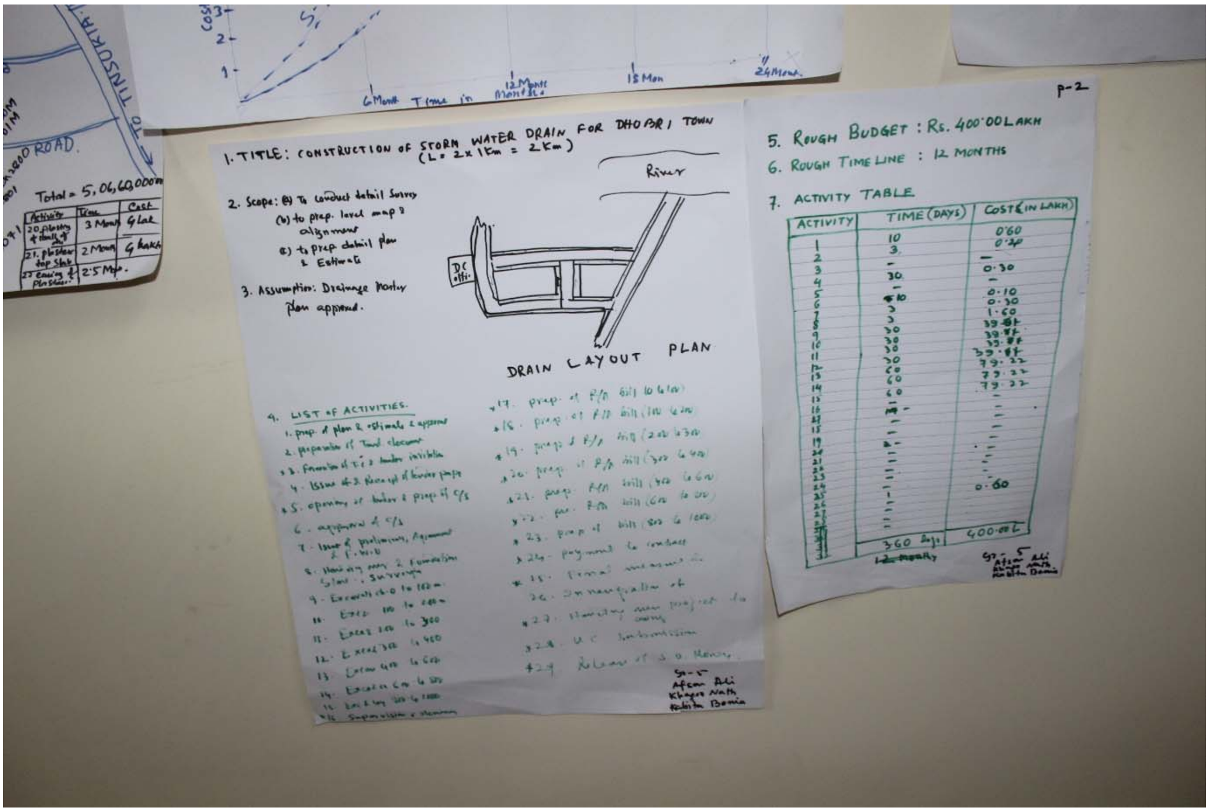

ACTIVITY
TIME
COST
CRITICAL PATH
Group No: 6
SUSTAINABLE
INTRODUCTION
SCOPE
ASSUMPTIONS/EXCLUSIONS
S Curve



- Overhead foot bridge at
- Exclusion of Dhobi Ghat.
- Existing Ferry Ghat.
CONSTRUCTION OF RETAINING WALL ALONG WITH STEPS & RAMPS
BOULDER PITCHING OF RIVER SLOPE
AND HANDOVER
GROUP NO. 6.
S. Curve
EV
Group: 6

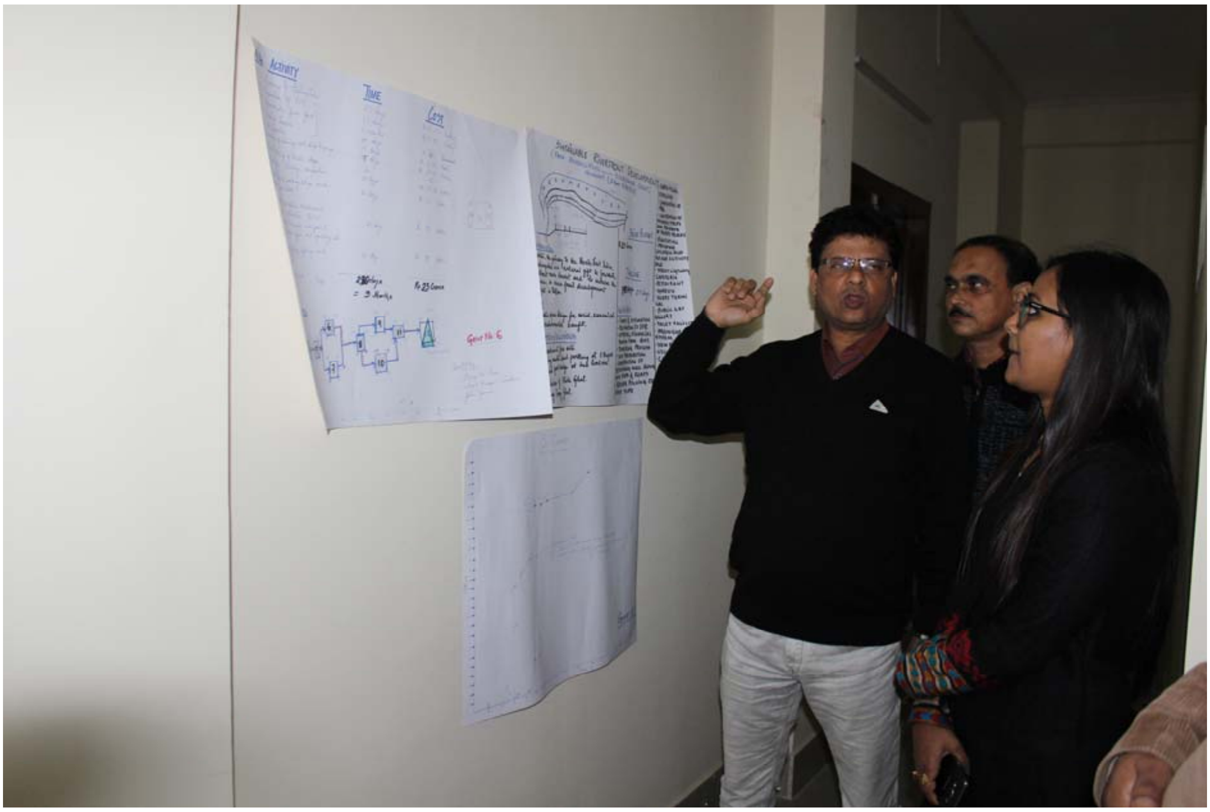

GROUP NO-1 SHEET NO-2
ACTIVITIES INVOVLES IN IMPLEMENTING THE PROJECT.
GROUP NO-1 FINDINGS OF CRITICAL PATH BY C.P.M. SHEET NO-3
S-CURVE
BRAHMA PUTRA
SITE PLAN
N.T.S.
CONVOY ROAD
TO TINSUKIA
Total = 5,06,60,000
1. TITLE: CONSTRUCTION OF STORM WATER DRAIN FOR DHOPAR TOWN
5. ROUGH BUDGET : Rs. 400·00
6. ROUGH TIME LINE : 12 MONTHS
7. ACTIVITY TABLE


C.P.M. SHEET NO-3
C P M
P-3
Cost (in Lakhs)
Time (in days)
P-2
5. ROUGH BUDGET : Rs. 400·00 LAKH
6. ROUGH TIME LINE : 12 MONTHS


1. TITLE: CONSTRUCTION OF STORM WATER DRAIN FOR DHUBRI TOWN
(L = 2 x 1 km = 2 km)
2. Scope: (a) To conduct detail Survey
(b) to prep. level map & alignment
(c) to prep detail plan & Estimate
3. Assumption: Drainage Master plan approved.
River
DRAIN LAYOUT PLAN
4. LIST OF ACTIVITIES.
5. ROUGH BUDGET : Rs. 400·00 LAKH
6. ROUGH TIME LINE : 12 MONTHS
7. ACTIVITY TABLE
ACTIVITY
TIME (DAYS)
COST (IN LAKH)
360 Days
400·00 L
12 Months
Afsar Ali
Total = 5,06,60,000
Time in Months
12 Month
18 Mon
24 Mon
p-2


CPM FOR INSTALLATION OF
AUTOMATIC TRAFFIC SIGNAL SYSTEM
TOWN.


FOR SILCHAR
GROUP-4
COST


Activity
Time
Cost
Group No-6


GROUP NO-1
TITLE OF THE PROJECT: CONST. OF
AT DIBRUGARH
SCOPE OF THE PROJECT:
ANY ASSUMPTION/EXPLOSION
BUDGET ALLOCATION
TIME OF COMPLETION
SITE PLAN


C P M
Time (in days)

Lecture on Drainage Design - Dr Bipul Talukdar

URBAN DRAINAGE MANAGEMENT

B. Talukdar, *Ph.D.*

Civil Engg. Department

Assam Engineering College

Assam flood : 5 died in Guwahati, over 13,000 affected across the state

India Blooms News Service | 14 Jun 2017

#Assam, #AssamFloods, #Floods

Guwahati, June 14 (IBNS): The first wave floods that hit Assam claimed five lives so far, while over 13,000 people have been affected in four districts of the state in the fresh floods.

Smart City in the making, Guwahati finds no easy answers to flooding

Geography, absence of a sewerage system and recent encroachment leave Guwahati vulnerable.

Written by Samudra Gupta Kashyap |Guwahati |Updated: July 12, 2016 7:25:33 am

Excessive amounts of litter in a drainage channel in Dhaka

Source: Urban Stormwater Management in Developing Countries, 2005 Photo: Birgitte Helwigh

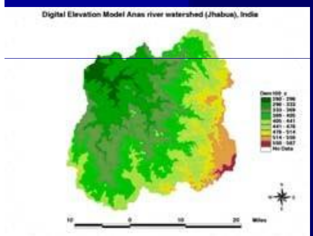
Blocked inlet to the stormwater drainage system in Dhaka

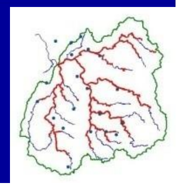
Source: Urban Stormwater Management in Developing Countries, 2005 Photo: Birgitte Helwigh

Karachi, Pakistan – 19th August 2006
Power supply,telecommunication,moblie systems disrupted
Rain related death toll: 26
Rain: 50-60 mm…..

Urban Drainage System

- **Topics Covered**
- Urban flooding, Urban drainage system, design requirements, Roadside drainage design
- Keywords: Urban flooding, drainage system design, roadside drain.



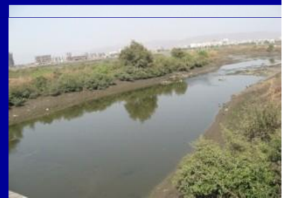


Causes of Urban Flooding

- Why urban flooding?. –
  - large increase in concrete/ impervious surface?.
  - Unplanned usage of urban land?.
  - Lack of proper drainage?.
  - Loss of wetlands?.
  - Less groundwater usage / recharge?.
  - Tidal effects?.
  - Very heavy storms – cloud burst?.

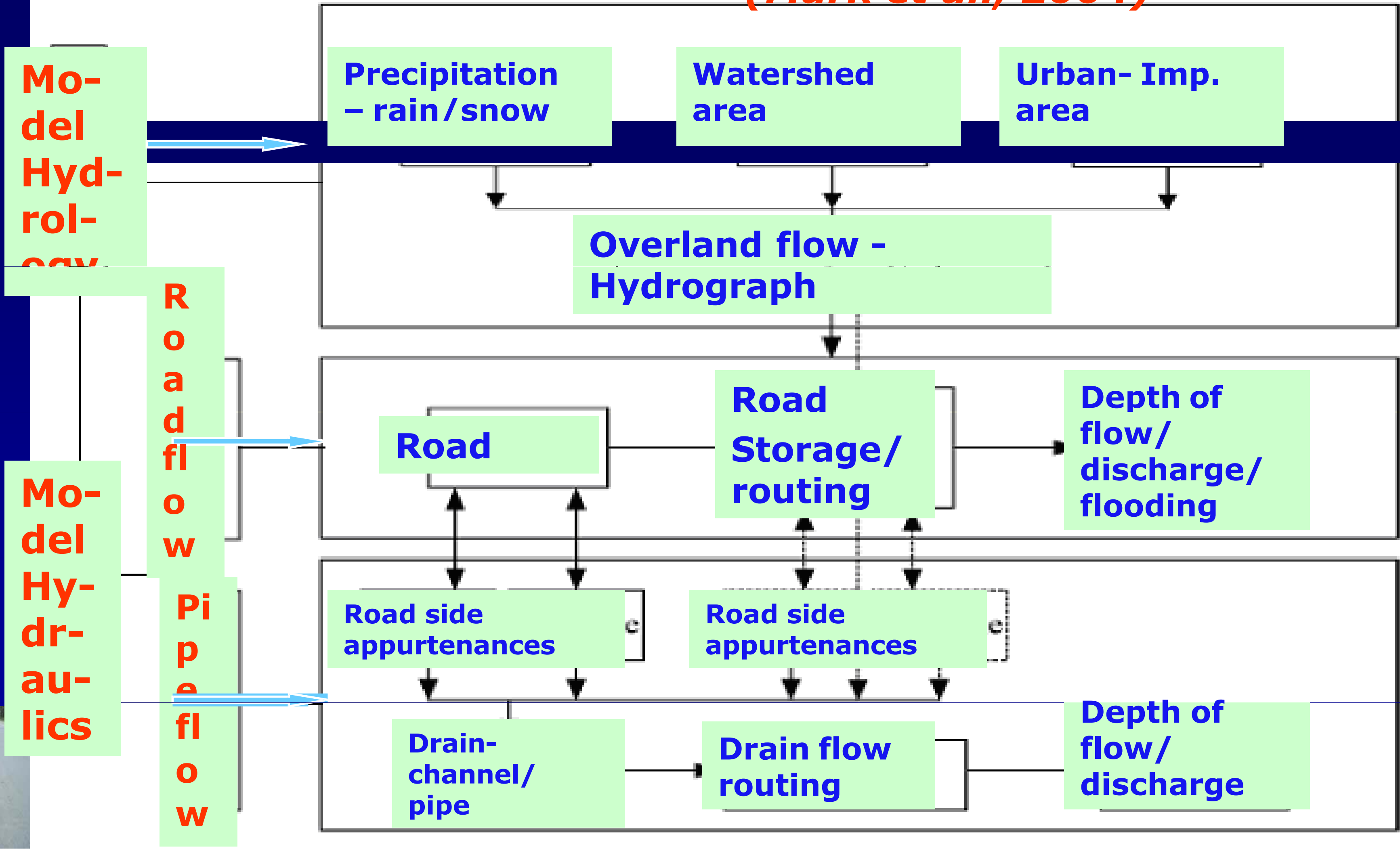
Urban Drainage System

- Drainage systems categorized as major & minor systems.
- Major drainage system - comprises of open nallahs/ and natural surface drains, etc.
- Minor system - network of underground pipes & channels.
- Minor system categorized into two types: separate & combined.
- Separate drainage systems consist of two conveyance networks: sanitary sewers (usually underground pipes) conveying wastewater from homes & businesses to a discharge point, while the storm drains (underground



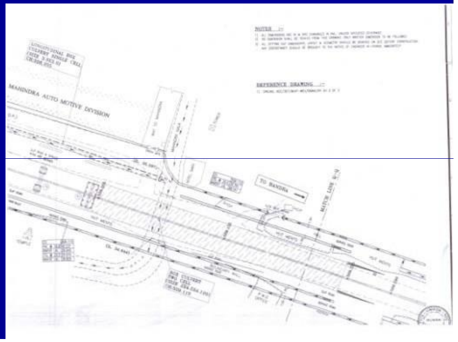
Urban Drainage - Processes

(Mark et al., 2004)



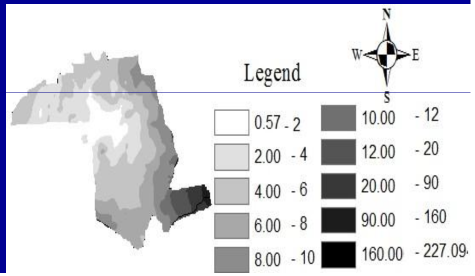
Stormwater Drainage System

- Total stormwater system – major & minor – inventory of the system for better management – GIS platform.
- Inventory will be both watershed based to enable proper hydrologic & hydraulic analysis & ward based to enable coordinated administrative management
- Minor systems should be mapped clearly showing the interconnections with major system besides the cross connections with sewer lines
- Major systems - be mapped clearly with delineation, demarcation & details of cross-sections, slopes, drain crossings including natural formations & man made structures



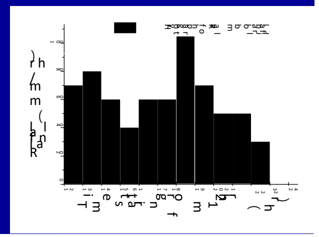
Urban Drainage Design - Requirements

- Development of an adequate & functioning drainage system based on sound hydrologic & hydraulic design principles.
- Design of an urban drainage system requires knowledge of the catchment area and topography, urbanization details, rainfall intensity, hydrology, hydraulics, etc.
- Watershed/ Catchment as basis of urban drainage design
- Contours are necessary for determining the boundaries of a watershed/ catchment & for computing directions of flow.



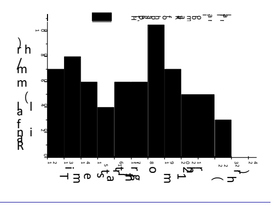
Urban Drainage Design - Requirements

- Rainfall data: For design of a drainage system, the conventional practice is to choose an appropriate, statistically relevant design storm to establish the stormwater flows to be conveyed, based on existing national & international practices.
- Design storms can be estimated from rainfall data records where available.
- Up to date IDF (Intensity Duration Frequency) relationships need to be used to maintain design standards for new systems & retrofitting/replacement of old urban drainage systems.
- IDF curves should be developed for each city, based on extraction of data from the raw data charts at min. 15-minutes resolution



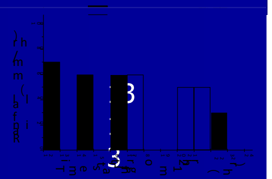
Urban Drainage Design Considerations

- Frequency of thunderstorms - additional consideration for planning future urban drainage systems.
- Design flow: To protect urban areas, safe management & passage of water, resulting from frequent storm events (hydrologic design aspects) & adequate capacity (hydraulic design aspects) must be considered.
- Urban Drainage Design: main objectives of hydrologic analysis & design are to estimate peak flow rates &/or flow hydrographs for the adequate sizing & design of conveyance & quantity control facilities
- To estimate peak flow rates, knowledge of the rainfall intensity, its duration & frequency is required



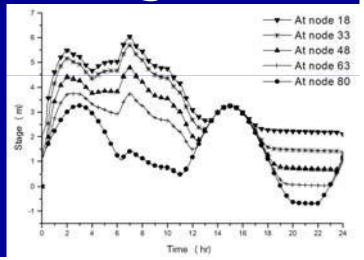
Urban Drainage Design-Problems

- Increasing rainfall intensities induced by climate change, urban heat islands and other factors, will possibly result in varying return periods for a given intensity of rainfall.
- Rainfall intensity to be used for design will also depend on the time of concentration.
- Higher the catchment area, higher will be the time of concentration & lower will be the design rainfall intensity, other factors remaining the same.
- Peak flow rates can be estimated using Rational Method Q = C I A.
- Approximations based on run-off coefficient, rainfall intensity & area of catchment



Design Considerations

- Simple channel design: Manning's equation:
  $Q = AR^{2/3}S^{1/2}/n$
- For computation of water level profiles in the drainage systems or channels/rivers, suitable software for flood routing should be used.
- Public domain software - HEC-HMS for hydrologic modelling of the watershed, HEC-RAS for river modeling, SWMM (Stormwater Management Model) for sewer/ drainage design
- All future stormwater drainage systems may be designed taking into consideration a runoff coefficient of upto C = 0.95 for estimating peak discharge using the rational method



UDS - Operation & Maintenance

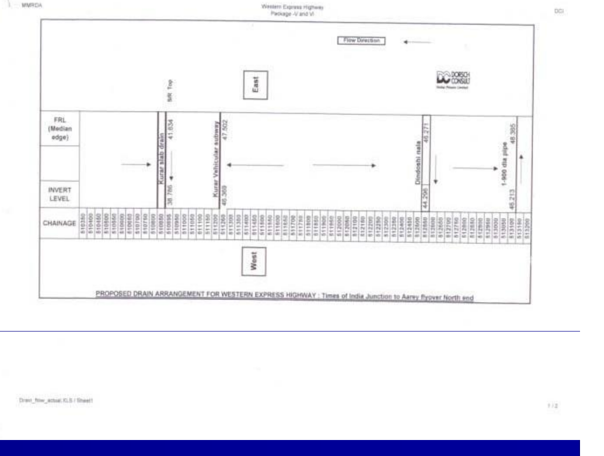
- Proper operations and maintenance (O&M) are crucial for any system to be functional to the designed capacity & for its durability as well.
- Pre-monsoon desilting -a major O&M activity.
- Periodicity of cleaning of drains should be worked out, based on the local conditions.
- Removal solid waste: Suitable interventions in the drainage system like traps, trash racks can reduce the amount of solid waste going into the storm sewers
- Removal of sediment
- Drain inlet connectivity

UDS – Special Considerations

- Low-lying areas should be reserved for parks and other low-impact human activities,
- Wherever unavoidable, buildings in low lying areas should be constructed on stilts above the High Flood Level (HFL)/ Full Tank Level (FTL)
- For chronic flooding spots, alternate locations may be explored for accommodating people staying there
- Buildings should be constructed on stilts after taking into account the stability of slopes, and
- Stormwater drainage systems for coastal cities have to be designed taking into account the tidal variations.

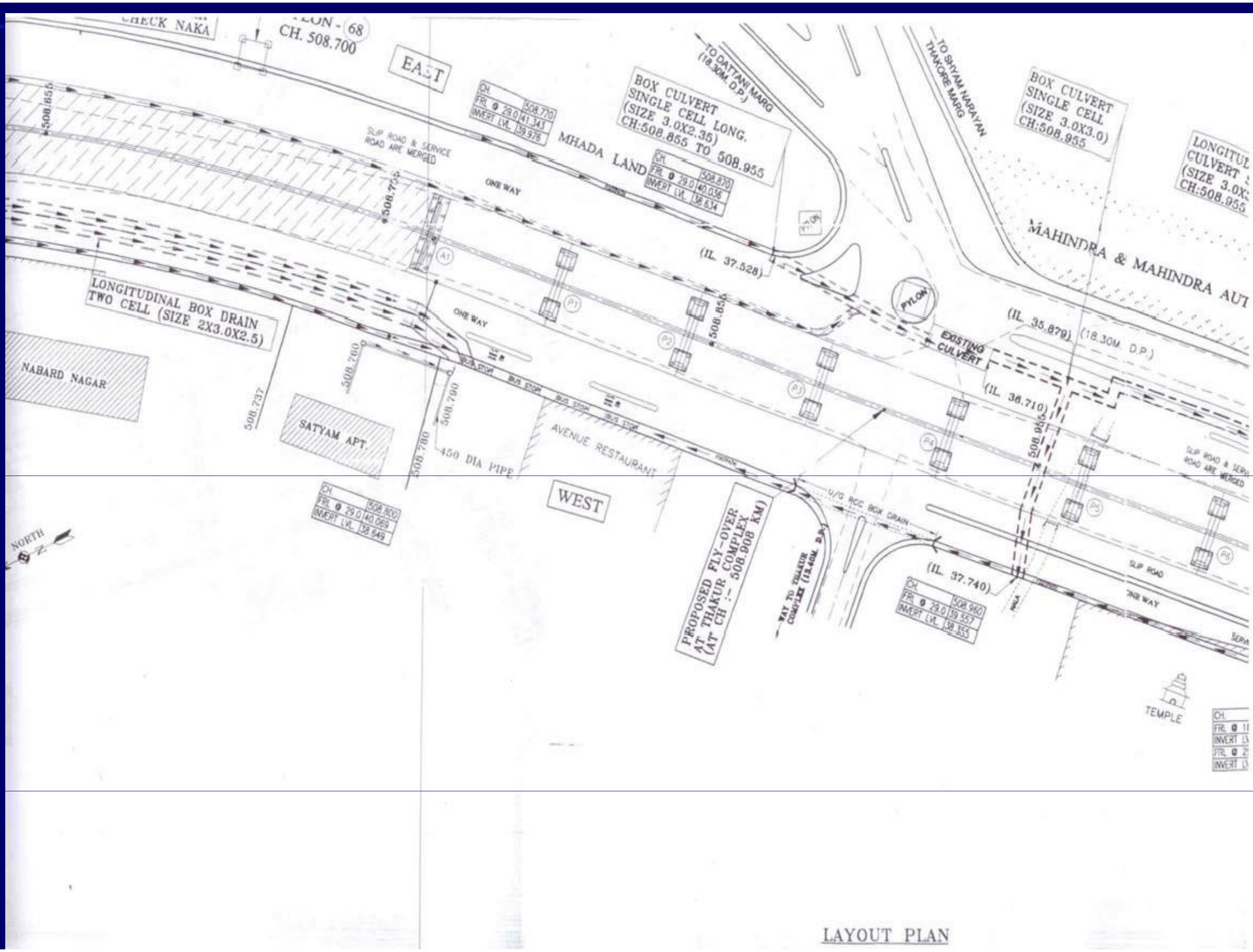
Road Side Drainage

- Road side drain: Integral part of urban drainage system
  - **Storm Drainage**
    - Collect storm water runoff
      - Away from structures
        - Through roadway and/ waterway
        - Right-of-way



- Objectives
  - Appropriate design – Hydrologic & hydraulic considerations
  - Minimize the flooding and erosion to properties
  - Safe traffic

Road Side Drainage – Design



Road Side Drainage – Design Steps

- Design Problem and design criteria specification
  - Type, specific locality
- – System drainage area definition and preliminary layout
  - Street layout, total drainage area to be handled
- – Field and office data collection
  - Make field visit, site specific problems (no width, trees, outcrops, utility locations, etc.
- – System layout
  - Final layout, all ditches, waterways, inlets, manholes, mains, laterals, culverts, flow direction, etc.

Road Side Drainage – Design Steps

Discharge, Froude number, velocity, slope

Drainage Design - Factors

- – Return period of flood (rainfall)
- – Spread
- – Inlet types and spacing
- – Longitudinal slope; Cross slope
- – Curb and gutter section
- – Roadside and median channels
- – Bridge decks / fly over
- – Shoulder gutter
- – Median barriers
- – Storm drains
- – Detention storage; Erosion
- – Cost

www.greenhighwayspartnership.org

Important Design Considerations

1. How much area should be considered for a reach?

- Actual length is in-between hydrologic mount to draining point

2. How much width should be considered on other side of the road drainage?

- Internationally road side drain are designed to cater "only road run-off", but in highly populated area it may be designed to carry run-off from near-by area also

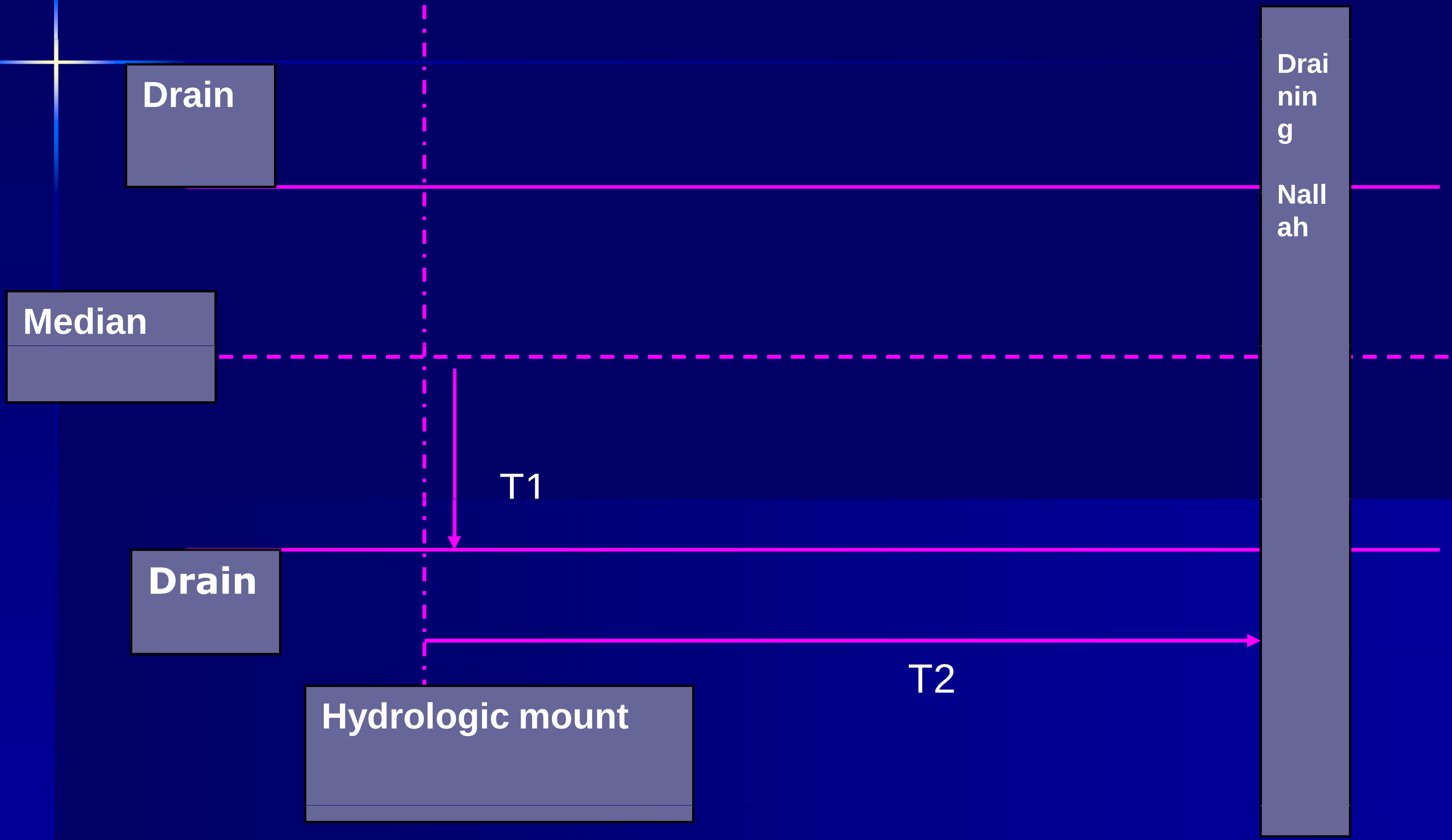
Important Design Considerations

- Actual width should be based on topographical survey
  - The actual area contributing to road side drain is not known

3) Designed rainfall intensity?

- Generally rainfall intensity with 10 year return period
- For important roads it should be 50 year return period
  - It should be based on time of concentration, IDF curves
  - IRC recommends time of concentration as: made of two time periods: 1.Time required for the rain water to flow over the road surface and enter into the drain (T1); 2. Time of flow in drains (T2)

Time of concentration = T1+T2



Important Design Considerations

- As per IRC 50: For Mumbai the critical intensity of rainfall is 50 mm/hr
- The values are worked out assuming
  - Time of concentration of 30 mints
  - Rate of rainfall is 62.5 mm/hr (return period 2 years)

  4) Average runoff coefficient (C) of 0.6

Type of surface	**Range of C**
Bituminous and cement concrete pavement	0.8- 0.9
Gravel and WBM pavement	0.35-0.70
Impervious soil	0.40-0.65
Soil covered with turf	0.30-0.55
Pervious soil	0.05-0.30

Important Design Considerations

5) Manning's Coefficient value?

- For concrete channels it is 0.013 to 0.017

6) Permissible velocity in the drains?

- For RCC drains - allowable is 6 m/s but practically it was restricted 3 m/s.

Surface Characteristics	**Range of n**
Concrete:	
a) Formed, no finish	0.013 to 0.017
b) Trowel finish	0.011 to 0.015
c) Float finish	0.013 to 0.015
d) Gunite, good section	0.016 to 0.019
e) Gunite, wavy section	0.018 to 0.022

Important Design Considerations

7) Width and depth?

- The width is as per the local width available for the construction of the drains
- Depth should be estimated based on Manning’s formula
- As far as possible rectangular
- Economical section is b=2d
- Some places pipes were also used

AS per IRC 50: Minimum width of drain should not be less than 250 mm and incase of pipe the minimum diameter should not be less than 450 mm.

8. Slope of the drains? Longitudinal slope?

- Generally slope should not be less than 0.3%
- But in flat terrain it can go upto 0.2%
- Slope is designed such that the flow is always in sub-critical flow
  - To avoid hydraulic jump

9. Free board?

- Generally for open channels a free board of 0.3 m is provided
- But Mumbai is having very flat terrain and does not allow to have more free board.

- IRC recommends the following free boards

Bed width	Free board
< 300 mm	10 cm
300 to 900 mm	15 cm
900 to 1500 mm	30 cm
Larger size	90 cm

Data Needed for the design

- I Rainfall intensity
- Runoff coefficient
- Area contributing to drains (length and width)
- Cross-sectional parameters of the road
- RL of the hydraulic mount
- RL of the ground level, IL of the drains

II. KEY PLAN OF THE WORK

the length

location of nallah

size, IL of drains at starting point and draining point

Slope between the sections

Other major drainage work nearby/ or river nearby

Data Needed for the design

III. DETAILED PLAN OF THE ROAD

- Length (in terms of chainage)
- Location of point sources and their discharge
- Hydrologic mount
- RL of ground levels at chainage points and other important points
- Arrows showing the flow direction of storm water in the drains
- Location of draining nallah
- Location and size of cross drainage work
- Location of man holes and their sizes
- Any other item relevant to the site specific design (to be highlighted)

References

- American Society of Civil Engineers and Water Environment Federation (ASCE and WEF). 1998. *Urban Runoff Quality Management.* WEF Manual of Practice No. 23, ASCE Manual and Report on Engineering Practice No. 87.
- *http://ndma.gov.in/ndma/guidelines.html*
- http://www.epa.gov/oaintrnt/stormwater/index.htm
- Mark, O., Weesakul, S., Apirumanekul, C., Aroonnet, S.B., Djordjevic, S. (2004). "Potential and Limitations of 1D Modelling of Urban Flooding." *J.Hydrology*, 299, 284-299
- National Disaster Management Guidelines (2010) – Managemnet of urban flooding, Gov. of India, New Delhi.
- National Research Council of the National Academies (NRC). 2008. "Urban Stormwater Management in the Unites States." The National Academies Press. Washington, DC.

5.5.2 Rainfall–Runoff Correlation

The relationship between rainfall in a period and the corresponding runoff is quite complex and is influenced by a host of factors relating to the catchment and climate. Further, there is the problem of paucity of data which forces one to adopt simple correlations for adequate estimation of runoff. One of the most common methods is to correlate seasonal or annual measured runoff values *(R)* with corresponding rainfall *(P)* values. A commonly adopted method is to fit a linear regression line between R and P and to accept the result if the correlation coefficient is nearer unity. The equation of the straight-line regression between runoff R and rainfall P is

$$\boxed{R = aP + b} \tag{5.2}$$

and the values of the coefficent a and b are given by

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma P)^2} \tag{5.3a}$$

and
$$b = \frac{\Sigma R - a(\Sigma P)}{N} \tag{5.3b}$$

in which N = number of observation sets R and P. The coefficient of correlation r can be calculated as

$$r = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{\sqrt{[N(\Sigma P^2) - (\Sigma P)^2][N(\Sigma R^2) - (\Sigma R)^2]}} \tag{5.4}$$

The value of r lies between 0 and 1 as R can have only positive correlation with P. The value of $0.6 < r < 1.0$ indicates good correlation. Further, it should be noted that $R \geq 0$. The term r^2 is known as the *coefficient of determination.*

For large catchments, sometimes it is found advantageous to have exponential relationship as

$$\boxed{R = \beta P^m} \tag{5.5}$$

where β and m are constants, instead of the linear relationship given by Eq. (5.2). In that case Eq. (5.5) is reduced to linear form by logarithmic transformation as

$$\ln R = m \ln P + \ln \beta \tag{5.6}$$

and the coefficients m and $\ln \beta$ are determined by using methods indicated earlier.

Since rainfall records of longer periods than that of runoff data are normally available for a catchment, the regression equation [Eq. (5.2) or (5.5)] can be used to generate synthetic runoff data by using rainfall data. While this may be adequate for preliminary studies, for accurate results sophisticated methods are adopted for synthetic generation of runoff data. Many improvements of the above basic rainfall-runoff correlation by considering additional parameters such as soil moisture and antecedent rainfall have been attempted. Antecedent rainfall influences the initial soil moisture and hence the infiltration rate at the start of the storm. For calculation of the annual runoff from the annual rainfall a commonly used antecedent precipitation index P_a is given by

$$P_a = aP_i + bP_{i-1} + cP_{i-2} \tag{5.7}$$

where P_i, p_{i-1} and P_{i-2} are the annual precipitation in the i^{th}, $(i-1)^{th}$ and $(i-2)^{th}$ year and i = current year, a, b and c are the coefficients with their sum equal to unity. The coefficients are found by trial and error to produce best results. There are many other types of antecedent precipitation indices in use to account for antecedent soil moisture condition. For example, in *SCS–CN* method (Sec. 5.6) the sum of past five-day rainfall is taken as the index of antecedent moisture condition.

Example 5.2 Annual rainfall and runoff values (in cm) of a catchment spanning a period of 21 years are given below. Analyse the data to (a) estimate the 75% and 50% dependable annual yield of the catchment, and (b) to develop a linear correlation equation to estimate annual runoff volume for a given annual rainfall value.

Year	Annual rainfall (cm)	Annual runoff (cm)	Year	Annual rainfall (cm)	Annual runoff (cm)
1975	118	54	1986	75	17
1976	98	45	1987	107	32
1977	112	51	1988	75	15
1978	97	41	1989	93	28
1979	84	21	1990	129	48
1980	91	32	1991	153	76
1981	138	66	1992	92	27
1982	89	25	1993	84	18
1983	104	42	1994	121	52
1984	80	11	1995	95	26
1985	97	32			

Solution

(*a*) The annual runoff values are arranged in descending order of magnitude and a rank (m) is assigned for each value starting from the highest value (Table 5.1). The exceedence probability p is calculate for each runoff value as $p = \frac{m}{N+1}$. In this m = rank number and N = number of data sets. (Note that in Table 5.1 three items have the same value of R = 32 cm and for this set p is calculated for the item having the highest value of m, i.e m = 12). For estimating 75% dependable yield, the value of p = 0.75 is read from Table 5.1 by linear interpolation between items having p = 0.773 and p = 0.727. By this method, the 75% dependable yield for the given annual yield time series is found to be R_{75} = 23.0 cm.

Similarly, the 50% dependable yield is obtained by linear interpolation between items having $p = 0.545$ and $p = 0.409$ as $R_{50} = 34.0$ cm.

(*b*) The correlation equation is written as $R = aP + b$

The coefficients of the best fit straight line for the data are obtained by the least square error method as mentioned in Table.

From Table 5.1,

$$\Sigma P = 2132 \qquad \Sigma R = 759 \qquad \Sigma PR = 83838$$

$$\Sigma P^2 = 224992 \qquad \Sigma R^2 = 33413$$

$$(\Sigma P)^2 = 4545424 \qquad (\Sigma R)^2 = 576081 \qquad N = 21$$

By using Eq. (5.3-a),

$$a = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{N(\Sigma P^2) - (\Sigma R)^2} = \frac{(21 \times 83838) - (2132)(759)}{(21 \times 224992) - (2132)^2} = 0.7938$$

Table Calculations *for Example 5.2*

1	2	3	4	5	6	7	8	9
Year	*P* rainfall (cm)	*R* runoff (cm)	P^2	R^2	*PR*	rank, *m*	*R* (Sorted annual runoff) (cm)	Exceedance probability, *p*
1975	118	54	13924	2916	6372	1	76	0.045
1976	98	45	9604	2025	4410	2	66	0.091
1977	112	51	12544	2601	5712	3	54	0.136
1978	97	41	9409	1681	3977	4	52	0.182
1979	84	21	7056	441	1764	5	51	0.227
1980	91	32	8281	1024	2912	6	48	0.273
1981	138	66	19044	4356	9108	7	45	0.318
1982	89	25	7921	625	2225	8	42	0.364
1983	104	42	10816	1764	4368	9	41	0.409
1984	80	11	6400	121	880	10	32	50%
1985	97	32	9409	1024	3104	11	32	12th
1986	75	17	5625	289	1275	12	32	0.545
1987	107	32	11449	1024	3424	13	28	0.591
1988	75	15	5625	225	1125	14	27	0.636
1989	93	28	8649	784	2604	15	26	0.682
1990	129	48	16641	2304	6192	16	25	0.727 75%
1991	153	76	23409	5776	11628	17	21	0.773
1992	92	27	8464	729	2484	18	18	0.818

(*Contd.*)

Table *(Contd.)*

1993	84	18	7056	324	1512	19	17	0.864
1994	121	52	14641	2704	6292	20	15	0.909
1995	95	26	9025	676	2470	21	11	0.955
SUM	**2132**	**759**	**224992**	**33413**	**83838**			

By Eq. (5.3-b)

$$b = \frac{\Sigma R - a(\Sigma P)}{N} = \frac{(759) - 0.7938 \times (2138)}{21} = -44.44$$

Hence, the required annual rainfall–runoff relationship of the catchment is given by

$R = 0.7938\,P - 44.44$ with both P and R being in cm and $R \geq 0$.

By Eq. (5.4) coefficient of correlation,

$$r = \frac{N(\Sigma PR) - (\Sigma P)(\Sigma R)}{\sqrt{[N(\Sigma P^2) - (\Sigma P)^2][N(\Sigma R^2) - (\Sigma R)^2]}}$$

$$= \frac{(21 \times 83838 - (2132)(759)}{\sqrt{[(21 \times 224992) - (4545424)][(21 \times 33413) - (576081)}} = 0.949$$

As the value of r is nearer to unity the correlation is very good. Figure 5.5 represents the data points and the best fit straight line.

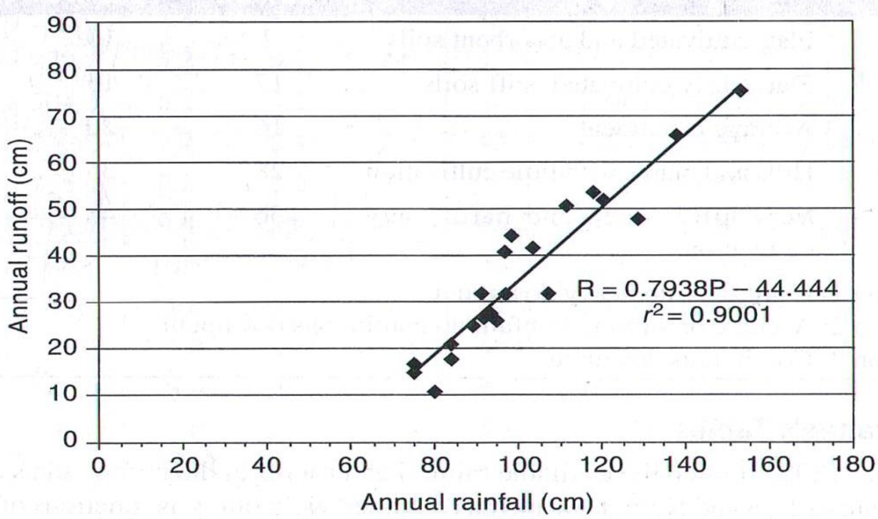


Fig. 5.7 ***Annual Rainfall–Runoff Correlation—Example 5.2***

5.5.3 Empirical Equations And Tables

The importance of estimating the water availability from the available hydrologic data for purposes of planning water-resource projects was recognised by engineers even in the nineteenth century. With a keen sense of observation in the region of their activity, many engineers of the past have developed empirical runoff estimation formulae. However, these formulae are applicable only to the region in which they were derived. These formulae are essentially rainfall–runoff relations with additional third or fourth parameters to account for climatic or catchment characteristics. Some of the important formulae used in various parts of India are given below.

1. Binnie's Percentages

Sir Alexander Binnie measured the runoff from a small catchment near Nagpur (Area of 16 km^2) during 1869 and 1872 and developed curves of cumulative runoff against cumulative rainfall. The two curves were found to be similar. From these, he established the percentages of runoff from rainfall. These percentages have been used in Madhya Pradesh and Vidarbha region of Maharashtra for the estimation of yield.

2. Barlow's Tables

Barlow, the first Chief Engineer of the Hydro-Electric Survey of India (1915) on the basis of his study in small catchments (area ~130 km^2) in Uttar Pradesh expressed runoff R as

$$R = K_b P \tag{5.8}$$

where K_b = runoff coefficient which depends upon the type of catchment and nature of monsoon rainfall. Values of K_b are given in Table 5.2.

Table 5.2 ***Barlow's Runoff Coefficient K_b in Percentage (Developed for use in UP)***

Class	Description of catchment	Values of K_b (percentage)		
		Season 1	Season 2	Season 3
A	Flat, cultivated and absorbent soils	7	10	15
B	Flat, partly cultivated, stiff soils	12	15	18
C	Average catchment	16	20	32
D	Hills and plains with little cultivation	28	35	60
E	Very hilly, steep and hardly any cultivation	36	45	81

Season 1: Light rain, no heavy downpour
Season 2: Average or varying rainfall, no continuous downpour
Season 3: Continuous downpour

3. Strange's Tables

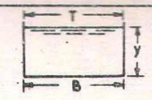
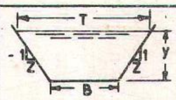
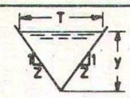
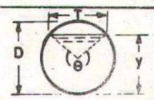
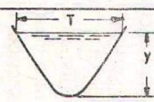
Strange (1892) studied the available rainfall and runoff in the border areas of present-day Maharashtra and Karnataka and has obtained yield ratios as functions of indicators representing catchment characteristics. Catchments are classified as *good, average* and *bad* according to the relative magnitudes of yield they give. For example, catchments with good forest/vegetal cover and having soils of high permeability would be classified as *bad,* while catchments having soils of low permeability and having little or no vegetal cover is termed *good.* Two methods using tables for estimating the runoff volume in a season are given.

(a) Runoff Volume from Total Monsoon Season Rainfall A table giving the runoff volumes for the monsoon period (i.e. yield during monsoon season) for different total monsoon rainfall values and for the three classes of catchments (viz. *good, average and bad)* are given in Table 5.3-a. The correlation equations of best fitting lines relating percentage yield ratio (Y_r) to precipitation (P) could be expressed as

Table 5.3(a) ***Strange's Table of Total Monsoon Rainfall and estimated Runoff***

Total Monsoon rainfall (inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall			Total Monsoon rainfall (inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall		
		Good catchment	Average catchment	Bad catchment			Good catchment	Average catchment	Bad catchment
1.0	25.4	0.1	0.1	0.1	31.0	787.4	27.4	20.5	13.7
2.0	50.8	0.2	0.2	0.1	32.0	812.8	28.5	21.3	14.2
3.0	76.2	0.4	0.3	0.2	33.0	838.2	29.6	22.2	14.8
4.0	101.6	0.7	0.5	0.3	34.0	863.6	30.8	23.1	15.4
5.0	127.0	1.0	0.7	0.5	35.0	889.0	31.9	23.9	15.9
6.0	152.4	1.5	1.1	0.7	36.0	914.4	33.0	24.7	16.5
7.0	177.8	2.1	1.5	1.0	37.0	939.8	34.1	25.5	17.0
8.0	203.2	2.8	2.1	1.4	38.0	965.2	35.3	26.4	17.6
9.0	228.6	3.5	2.6	1.7	39.0	990.6	36.4	27.3	18.2
10.0	254.0	4.3	3.2	2.1	40.0	1016.0	37.5	28.1	18.7
11.0	279.4	5.2	3.9	2.6	41.0	1 041.4	38.6	28.9	19.3
12.0	304.8	6.2	4.6	3.1	42.0	1066.8	39.8	29.8	19.9
13.0	330.2	7.2	5.4	3.6	43.0	1092.2	40.9	30.6	20.4
14.0	355.6	8.3	6.2	4.1	44.0	1117.6	42.0	31.5	21.0
15.0	381.0	9.4	7.0	4.7	45.0	1143.0	43.1	32.3	21.5
16.0	406.4	10.5	7.8	5.2	46.0	1168.4	44.3	33.2	22.1
17.0	431.8	11.6	8.7	5.8	47.0	1193.8	45.4	34.0	22.7
18.0	457.2	12.8	9.6	6.4	48.0	1219.2	46.5	34.8	23.2
19.0	482.6	13.9	10.4	6.9	49.0	1244.6	47.6	35.7	23.8
20.0	508.0	15.0	11.3	7.5	50.0	1270.0	48.8	36.6	24.4
21.0	533.4	16.1	12.0	8.0	51.0	1295.4	49.9	37.4	24.9
22.0	558.8	17.3	12.9	8.6	52.0	1320.8	51.0	38.2	25.5
23.0	584.2	18.4	13.8	9.2	53.0	1346.2	52.1	39.0	26.0
24.0	609.6	19.5	14.6	9.7	54.0	1371.6	53.3	39.9	26.6
25.0	635.0	20.6	15.4	10.3	55.0	1397.0	54.4	40.8	27.2
26.0	660.4	21.8	16.3	10.9	56.0	1422.4	55.5	41.6	27.7
27.0	685.8	22.9	17.1	11.4	57.0	1447.8	56.6	42.4	28.3
28.0	711.2	24.0	18.0	12.0	58.0	1473.2	57.8	43.3	28.9
29.0	736.6	25.1	18.8	12.5	59.0	1498.6	58.9	44.4	29.41
30.0	762.0	26.3	19.7	13.1	60.0	1524.0	60.0	45.0	30.0

GEOMETRIC ELEMENTS OF CHANNEL SECTIONS

SECTION		AREA A	WETTED PERIMETER P	HYDRAULIC RADIUS R	TOP WIDTH T	HYDRAULIC DEPTH D	SECTION FACTOR Z
RECTANGLE		By	$B+2y$	$\frac{By}{B+2y}$	B	y	$A\sqrt{D}$ $B(y)^{1.5}$ $=By^{3/2}$
TRAPEZOID		$(B+Zy)y$	$B+2y\sqrt{Z^2+1}$	$\frac{(B+Zy)y}{B+2y\sqrt{Z^2+1}}$	$B+2Zy$	$\frac{(B+Zy)y}{B+2Zy}$	$\frac{[(B+Zy)y]^{1.5}}{\sqrt{B+2Zy}}$
TRIANGLE		Zy^2	$2y\sqrt{Z^2+1}$	$\frac{Zy}{2\sqrt{Z^2+1}}$	$2Zy$	$\frac{1}{2}y$	$\frac{\sqrt{2}}{2}Z(y)^{2.5}$
CIRCLE		$\frac{1}{8}(\theta-\sin\theta)D^2$	$\frac{1}{2}\theta D$	$\frac{1}{4}\left(1-\frac{\sin\theta}{\theta}\right)D$	$D(\sin\frac{\theta}{2})$, or $2\sqrt{y(D-y)}$	$\frac{1}{8}\left(\frac{\theta-\sin\theta}{\sin\frac{\theta}{2}}\right)D$	$\frac{\sqrt{2}}{32}\frac{(\theta-\sin\theta)^{1.5}}{(\sin\frac{\theta}{2})^{0.5}}D^{2.5}$
PARABOLA		$\frac{2}{3}Ty$	$T+\frac{8}{3}\frac{y^2}{T}$	$\frac{2T^2y}{3T^2+8y^2}$	$\frac{3A}{2y}$	$\frac{2}{3}y$	$\frac{2}{9}\sqrt{6}\,Ty^{1.5}$

where R is the hydraulic radius and S_0 (= sin θ = S) is the slope of the channel bottom which for small values of θ may be considered equal to tan θ, since sin θ $\simeq$ tan θ.

In Chapter 13 the shear stress τ_0 has been related to mass density ρ and average velocity V by the equation $\tau_0 = \frac{f}{8}\rho V^2$. Thus equating the two expressions for τ_0, we get

$$wRS = \frac{f}{8}\rho V^2$$

or

$$V = \sqrt{\frac{8w}{\rho f}}\sqrt{RS} = \sqrt{\frac{8g}{f}}\sqrt{RS}$$

since $(w/\rho) = g$

The above expression is generally written as

$$V = C\sqrt{RS} \qquad \text{...(15·2)}$$

in which

$$C = \sqrt{\left(\frac{8g}{f}\right)}$$

Equation 15·2 is known as Chezy's formula named after the French Engineer Antoine Chezy who developed this formula in 1775. The term C is known as Chezy's coefficient. It may, however, be observed that the Chezy's coefficient C varies inversely as the square root of the Darcy-Weisbach resistance coefficient f. Further it may be noted that Chezy's coefficient is not a dimensionless coefficient but it has the dimensions $[L^{1/2}T^{-1}]$. Although Chezy's equation is quite simple the selection of a correct value of C is rather difficult. As such many empirical formulae have been developed to determine the value of Chezy's C. Some of the important formulae developed for this purpose are as noted below.

(*a*) **The Ganguillet-Kutter Formula.** On the basis of a series of flow measurements taken in channels of various types, two Swiss engineers Ganguillet and Kutter proposed an empirical formula in 1869, expressing the value of Chezy's C in terms of the slope S, hydraulic radius R and a roughness coefficient n. In SI or metric system the formula is

$$C = \frac{23 + \dfrac{0{\cdot}00155}{S} + \dfrac{1}{n}}{1 + \left(23 + \dfrac{0{\cdot}00155}{S}\right)\dfrac{n}{\sqrt{R}}} \qquad \text{...(15·3)}$$

The roughness coefficient n is known as Kutter's n. The value of n varies widely depending upon the channel surface and its condition. Some typical values of n for different types of surfaces commonly encountered in practice are given in Table 15·3.

(*b*) **The Bazin Formula.** In 1897, the French hydraulician H. Bazin proposed another empirical formula for Chezy's C. According to this formula Chezy's C is expressed in terms of hydraulic radius R and another roughness, factor m, known as Bazin's roughness coefficient. In metric system Bazin's formula may be expressed as

$$C = \frac{157 \cdot 6}{1 \cdot 81 + \frac{m}{\sqrt{R}}} \qquad ...(15 \cdot 4)$$

Some of the values of m proposed by Bazin are given in Table 15·2.

TABLE 15·2

VALUE OF BAZIN'S *M* FOR VARIOUS SURFACE MATERIALS

Type of Channel Boundary Surface	*m*
Very smooth cement, or planed wood	0·11
Concrete or brick or unplaned wood	.0·21
Ashlar, rubble masonry or poor brick work	0·83
Earth channels in very good condition	1·54
Earth channels in ordinary condition	2·36
Earth channels in rough condition	3·17

(*c*) **The Manning Formula.** In 1889 an Irish engineer Robert Manning presented a formula according to which the mean velocity V of uniform flow in a channel is expressed in terms of a coefficient of roughness n, called Manning's n, hydraulic radius R and channel bottom slope S. The Manning's formula expressed in SI or metric units is written as

$$V = \frac{1}{n} R^{2/3} S^{1/2} \qquad ...(15 \cdot 5)$$

Owing to its simplicity of form and to the satisfactory result it yields in practice, the Manning formula has now becomes the most widely used of all the empirical formula for the computation of uniform flow in open channels.

If the Manning formula is compared with the Chezy formula it can be seen that

$$C = \frac{1}{n} R^{1/6} \qquad ...(15 \cdot 6)$$

The equation 15·6 provides an important relationship between Chezy's C and Manning's n.

The values of Manning's n are found to be approximately equal to those of Kutter's n for the normal ranges of slope and hydraulic radius. Some of the typical values which hold good for both Kutter's n and Manning's n are given in Table 15·3.

TABLE 15·3

AVERAGE VALUES OF MANNING'S ROUGHNESS COEFFICIENT n

Type of channel boundary surface	*Value of n*
Very smooth surface such as glass, plastic or brass	0·010
Very smooth concrete and planed timber	0·011
Smooth concrete	0·012
Ordinary concrete lining	0·013
Glazed brick work	0·013
Good wood	0·014
Vitrified clay	0·014
Brick surface lined with cement mortar	0·015
Cement concrete finish	0·015
Unfinished cement surface	0·017
Earth channel in best condition	0·017
Neatly excavated rock	0·020
Straight unlined earth canals in good condition	0·020
Rubble masonry	0·020
Corrugated metal surface	0·020
Rivers and earth canals in fair condition	0·025
Earth channel with gravel bottom	0·025
Earth channel with dense weed	0·035
Mountain stream with rock beds and rivers with variable sections and some vegetation along banks	0·045

In addition to the above mentioned uniform-flow formulae, a few other formulae for uniform flow in channels have been derived on the basis of theoretical velocity distribution across the channel section. For turbulent flow in channels the velocity distribution can be shown to be approximately logarithmic. Thus using the Prandtl-von Karman universal velocity-distribution law *viz.*,

$$[(v/V_*) = 2{\cdot}5 \log_e y + C],$$

Keulegan has derived the following equations for the mean velocity of uniform turbulent flow in channels.

For smooth channels

$$(V/V_*) = 3{\cdot}25 + 5{\cdot}75 \log_{10}\left(\frac{RV_*}{\upsilon}\right) \qquad \ldots(15{\cdot}7)$$

For rough channels

$$(V/V_*) = 6{\cdot}25 + 5{\cdot}75 \log_{10}(R/k) \qquad \ldots(15{\cdot}8)$$

where V is mean velocity of flow, V_* is shear velocity, R is hydraulic radius, υ is kinematic viscosity and k is average height of roughness protrusions.

$$R = \frac{A}{P}$$

$$= \frac{(B + zy)y}{B + 2y\sqrt{1 + z^2}}$$

Substituting the values of B from equation 15·17 in the above expression, we get

$$R = \frac{(2y\sqrt{1 + z^2} - 2zy + zy)\,y}{2y\sqrt{1 + z^2} - 2zy + 2y\sqrt{1 + z^2}}$$

or $$R = \frac{y}{2} \qquad ...(15·18)$$

Thus it can be seen that for a trapezoidal channel section to be most economical the hydraulic radius must be equal to half the depth of flow.

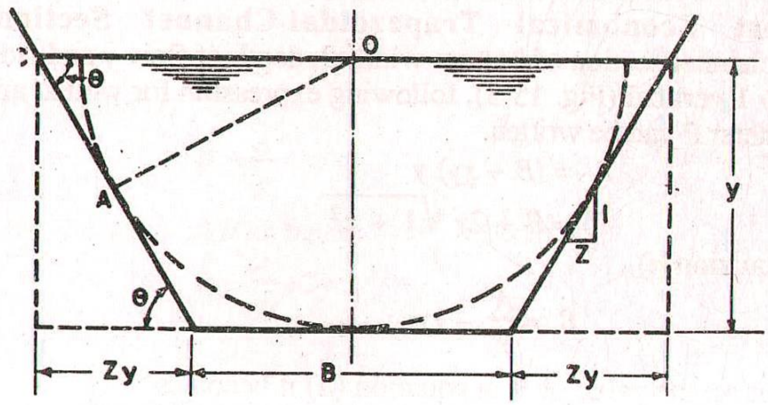


Fig. 15·5 Trapezoidal channel section

Further let O be the centre of top width of the trapezoidal channel section. Drop perpendicular OA from O to the sloping side of the channel, Fig. 15·5. If θ is the angle made by the sloping side with the horizontal, then from the right-angled triangle OAC, $OA = OC \sin\theta$.

But $$OC = \left(\frac{B + 2zy}{2}\right)$$

and $$\sin\theta = \frac{y}{y\sqrt{1 + z^2}}$$

$\therefore$ $$OA = \frac{B + 2zy}{2} \times \frac{y}{y\sqrt{1 + z^2}}$$

$$= \frac{B + 2zy}{2\sqrt{1 + z^2}}$$

Now substituting for $(B + 2zy)$ from equation 15·17, we obtain for most economical trapezoidal channel section

$$OA = y \qquad ...(15·19)$$

That is, if a semi-circle is drawn with O as centre and radius equal to the depth of flow y, the three sides of a most economical trapezoidal channel section, *viz.*, the bottom and the two sloping sides will be tangential to the semi-circle.

Thus equations 15·17, 15·18 and 15·19 represent the three conditions, either of which must be satisfied for a trapezodial channel section to be most economical.

The above derived conditions are based on the assumption that side slope z is constant. As such these conditions will not provide a most economical trapezoidal channel section if either the bottom width or the depth of flow has to be limited due to physical considerations. However, it is possible to derive the conditions which should be satisfied for a trapezoidal channel section to be most economical when either the bottom width or the depth of flow has to be kept constant. By adopting the same procedure as indicated above, the following two conditions can be obtained which may be used for the design of a most economical trapezoidal channel section.

(1) for the bottom width to be kept constant

$$\frac{B}{y} = \frac{1-z^2}{z} \qquad \ldots(15·20)$$

or

$$A = \frac{y^2}{z} \qquad \ldots(15·21)$$

(2) For the depth of flow to be kept constant

$$z = \frac{1}{\sqrt{3}};\ \text{or } \theta = 60° \qquad \ldots(15·22)$$

(*c*) **Most Economical Triangular Channel Section.** For a triangular channel section, if θ is the angle of inclination of each of the sloping sides with the vertical and y is the depth of flow (Fig.15·6), the following expression for the wetted area A and the wetted perimeter P can be written

$$A = y^2 \tan\theta$$

or

$$y = \sqrt{A/\tan\theta} \qquad \ldots(i)$$

$$P = (2y)\sec\theta \qquad \ldots(ii)$$

Substituting the value of y from equation (*i*) in equation (*ii*) it becomes

$$P = \frac{2\sqrt{A}}{\sqrt{\tan\theta}}(\sec\theta) \qquad \ldots(iii)$$

Assuming the area A to be constant, equation (*iii*) can be differentiated with respect to θ and equated to zero for obtaining the condition for minimum P.

Thus

$$\frac{dP}{d\theta} = 2\sqrt{A}\left[\frac{\sec\theta\tan\theta}{\sqrt{\tan\theta}} - \frac{\sec^3\theta}{2(\tan\theta)^{3/2}}\right] = 0$$

or
$$\sec\theta\,(2\tan^2\theta - \sec^2\theta) = 0$$

Since
$$\sec\theta \neq 0$$
$$2\tan^2\theta - \sec^2\theta = 0$$

or
$$\sqrt{2}\tan\theta = \sec\theta$$

$$\therefore \qquad \theta = 45^\circ \text{ ; or } z = 1 \qquad \text{...(15·23)}$$

Hence a triangular channel section will be most economical when each of its sloping sides makes an angle of 45° with the vertical.

The hydraulic radius R of a triangular channel section can be expressed as

$$R = \frac{A}{P} = \frac{y^2\tan\theta}{2y\sec\theta}$$

Substituting the valne of θ from equation 15·23 in the above expression

$$R = \frac{y}{2\sqrt{2}} \qquad \text{...(15·24)}$$

Thus it can be seen that the most economical triangular channel section will be half square described on a diagonal and having equal sloping sides.

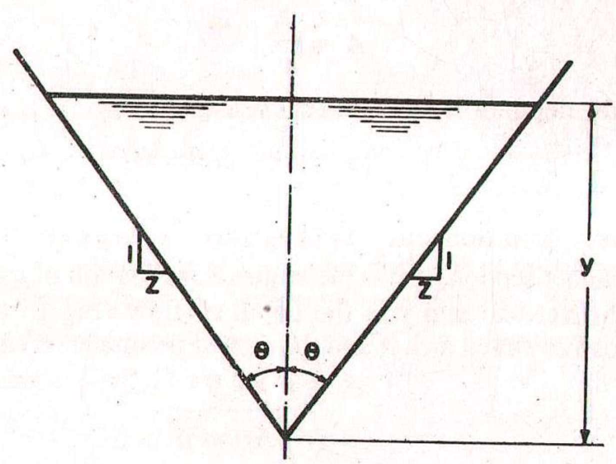


Fig. 15·6 Triangular channel section

It may, however, be noted that in all these cases the conditions for the discharge to be maximum would be the same if instead of the area of cross-section the perimeter is given.

(*d*) **Most Economical Circular Channel Section.** For a circular channel section of any radius, as the depth of flow varies, the shape of the flow area also varies due to the convergence of the boundaries towards the top. As such both the wetted area as well as the wetted perimeter varies with the depth of flow, and hence in the case of circular channels the condition of area of flow section being constant cannot be applied. Thus in the case of circular channels two separate conditions may be derived for the maximum discharge and the maximum mean velocity of flow, as indicated below.

Estimation of Peak Discharge

by

Dr. Bipul Talukdar

Civil Engineering Department

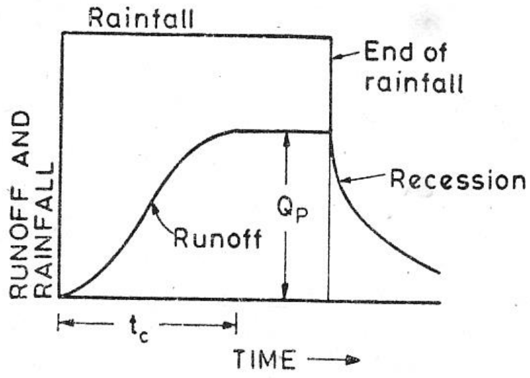
Assam Engineering College, Guwahati

Email : bipul.ce@aec.ac.in

A flood is an unusually high stage in a river, a level at which the river overflows the banks and innundates the adjoining area causing damages in terms of loss of life, property and economic loss due to disruptions of normal activities

Magnitudes of a flood peak can be estimated by:

1. **Rational method**
2. **Empirical method**
3. **Unit-hydrograph method**
4. **Flood frequency studies**



Runoff hydrograph due to uniform rainfall

Rational Method

$Qp=CiA, \quad t>t_c$

With commonly used units:

$Qp=1/3.6 \;\; Ci_{(tc,P)}A$

where Q_p = peak discharge (m^3/s)

C=coeff. of runoff

$i_{(tc,P)}$ = intensity of rainfall (mm/hr) for a duration equal to tc and exceedence probability P

A= drainage area (km^2)

Time of concentration (t_c)
Kirpich equation

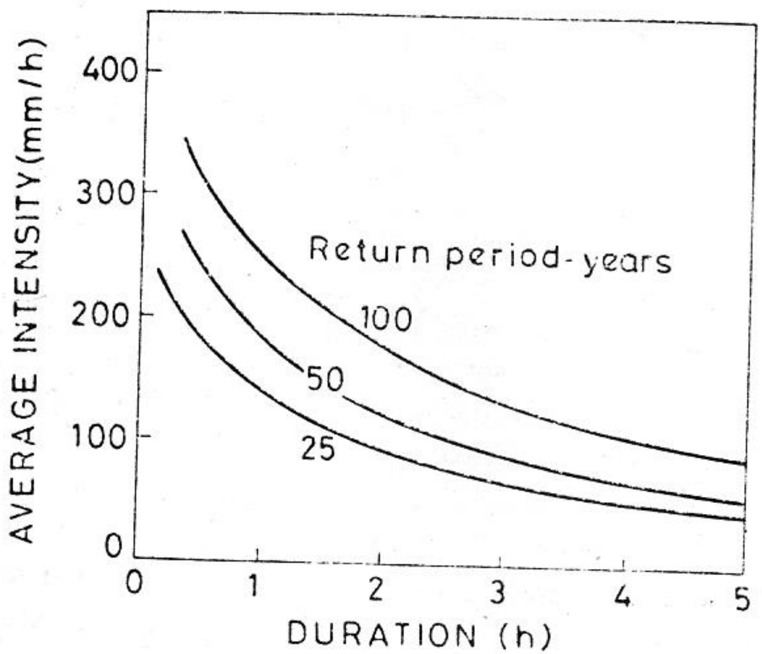
$$t_c = 0.01947\ L^{0.77}\ S^{-0.385}$$

t_c = time of concentration (minutes)
L = maximum length of travel of water (m)
S = slope of the catchment = $\Delta H/L$
ΔH = elevation difference between the most remote point on the catchment and the outlet

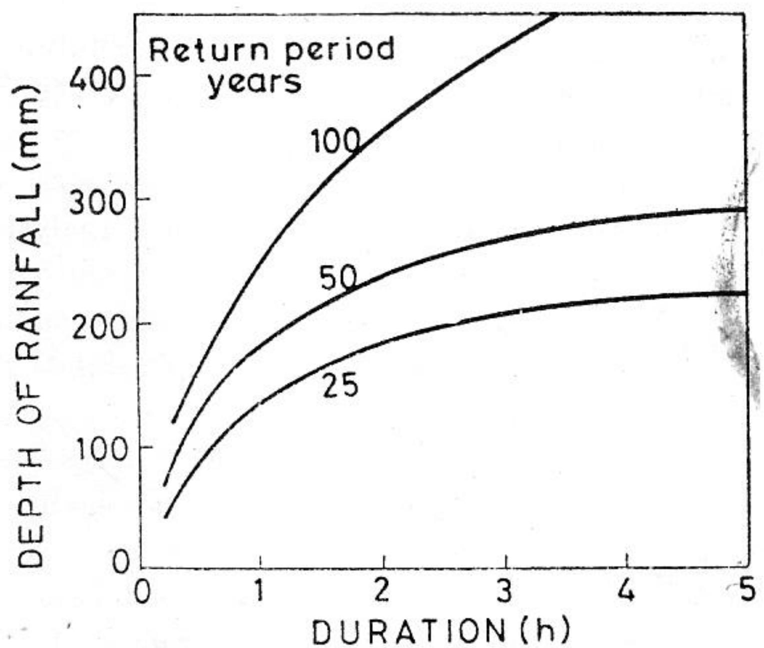
Rainfall intensity, $i_{(t_c,P)}$

$$i_{(t_c,P)} = \frac{kT^x}{(t_c + a)^m}$$

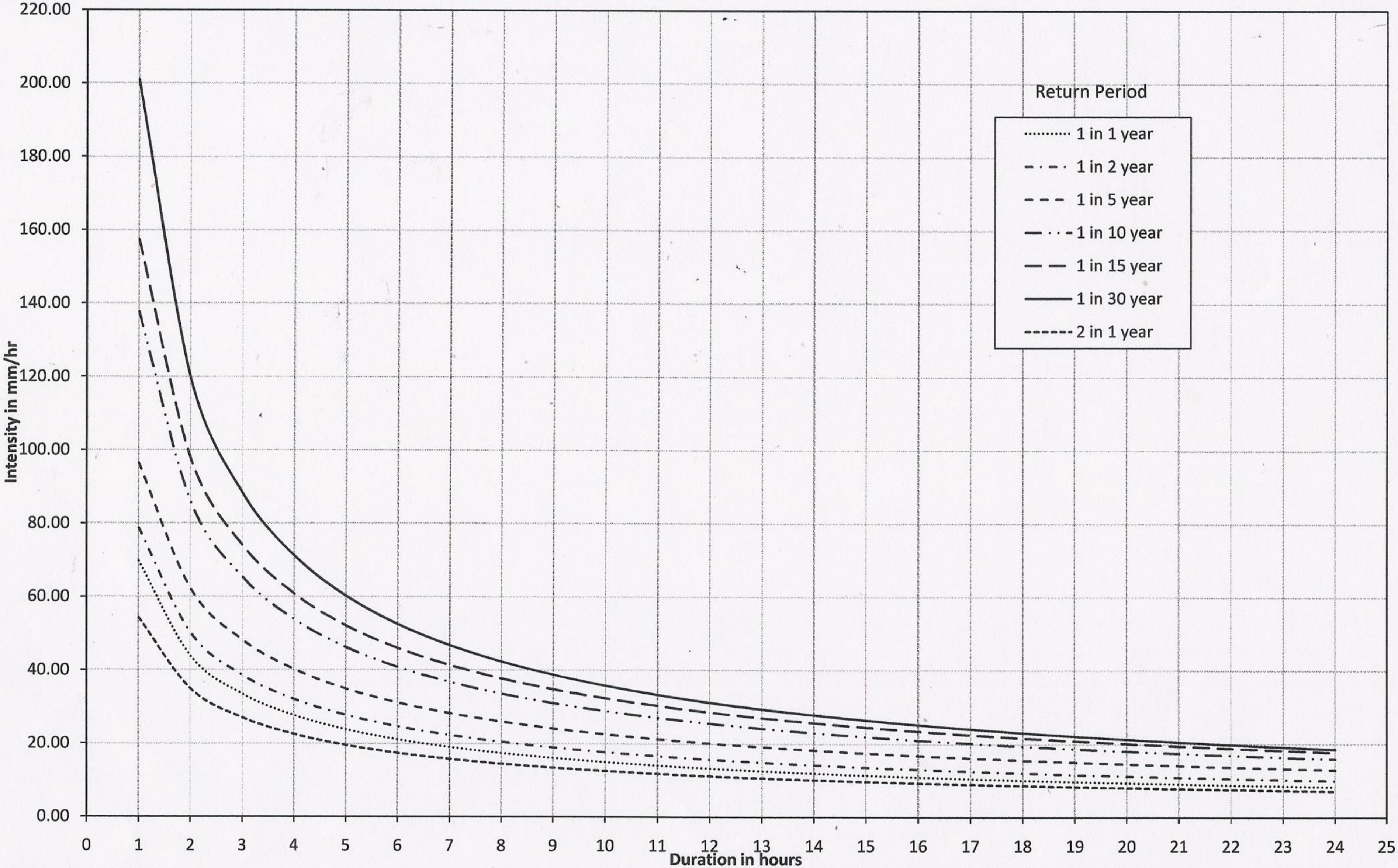
k,a,x,m are constants



Intensity–duration–frequency curves



Depth–duration–frequency curves



220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Intensity in mm/hr
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Duration in hours
Return Period
1 in 1 year
1 in 2 year
1 in 5 year
1 in 10 year
1 in 15 year
1 in 30 year
2 in 1 year

Determination of runoff coefficient C for various land usage

VALUE OF THE COEFFICIENT C

Type of area	Value of C
A. *Urban area* (P = 0.05 to 0.10)	
Lawns: Sandy-soil, flat, 2%	0.05–0.10
Sandy soil, steep, 7%	0.15–0.20
Heavy soil, average, 2-7%	0.18–0.22
Residential areas:	
Single family areas	0.30–0.50
Multi units, attached	0.60–0.75
Industrial: Light	0.50–0.80
Heavy	0.60–0.90
Streets	0.70–0.95
B. *Agricultural Area*	
Flat: Tight clay, cultivated	0.50
woodland	0.40
Sandy loam, cultivated	0.20
woodland	0.10
Hilly: Tight clay, cultivated	0.70
woodland	0.60
Sandy loam, cultivated	0.40
woodland	0.30

EMPIRICAL FORMULAE

Dickens formula $Q_p = C_D A^{3/4}$

C_D = Dicken's constant (6 to 30)

Ryves formula $Q_p = C_R A^{2/3}$

C_R = Ryves constant

= 6.8 for areas within 80 km from the east coast

= 8.5 for areas which are 80 t0 160 km from the east coast

Inglis formula

$$Q_p = \frac{124A}{\sqrt{A + 10.4}}$$

Fuller formula

$$Q_{T_p} = C_f A^{0.8}(1 + 0.8\log T)$$

Q_{T_p} = 24-hr peak flood with a frequency of T years (m3/s)

= Fuller's constant (0.18 to 1.88)

World enveloping flood formula

(J.M.Baird & J.F.Meillnraith)

$$Q = \frac{3010A}{(277 + A)^{0.78}}$$

used for preparing envelop curves

Determination of peak flood by UH method

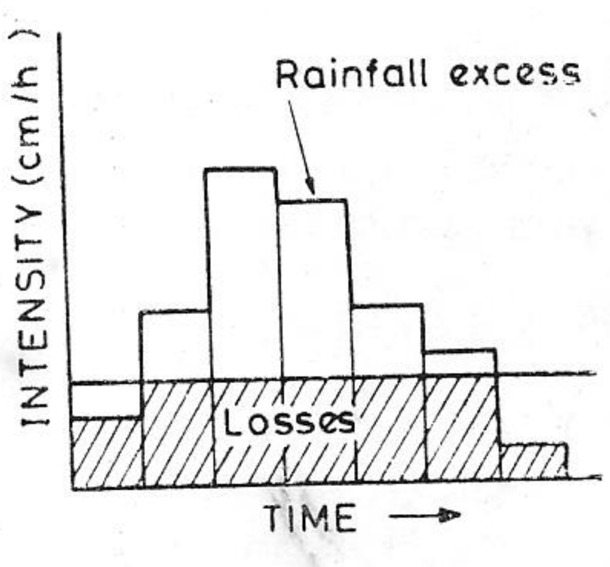
The following steps are involved

1.Select the design storm (by taking the hyetograph). Determine rainfall depth from the intensity-duration curve or DAD curve.

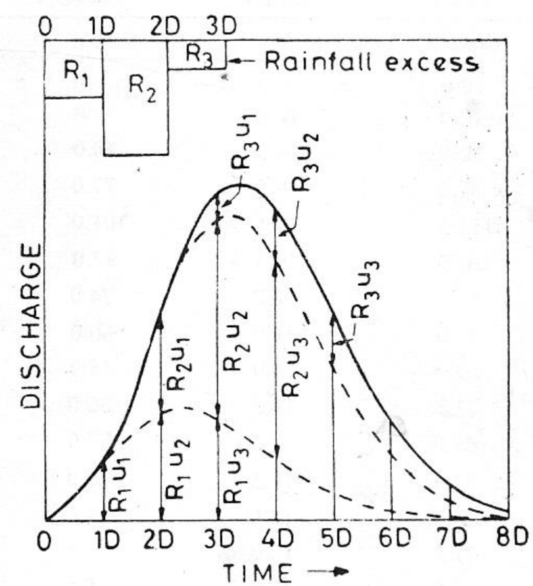
2. Estimate rainfall excess by considering the infiltration index for the catchment.

3. Select the appropriate UH (with appropriate duration) for the catchment. Multiply the ordinates of the UH by the rainfall excess and add the base flow.

In case of a storm with varying rainfall intensities, determine rainfall excess for each hour by subtracting the losses (infiltration, evapo-transpiration etc.). Determine the composite flood hydrograph by adding the flood hydrographs generated for every hour.

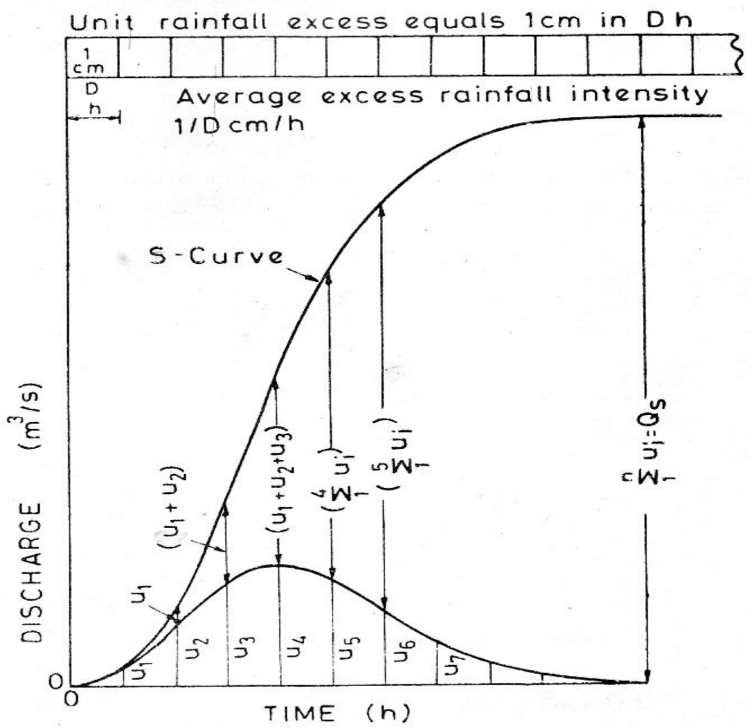


Effective rainfall hyetograph

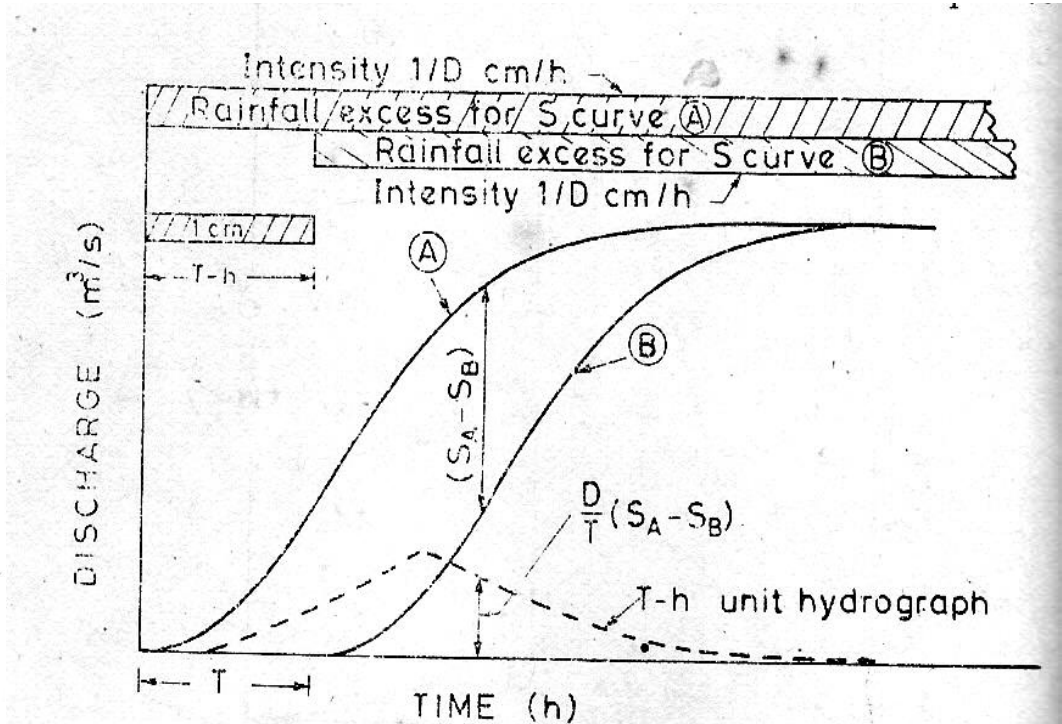


Unit hydrograph from a complex storm

Determination of S-curve



S-curve



Derivation of a *T*-h unit hydrograph by *S*-curve lagging method

Limitations of the UH method

Applicable for catchments of less than 5000 km^2 as the storm discharge is assumed to be uniform

For larger catchments:

1. sub-divide the catchment into a number of sub-catchments
2. Carry out UH applications for each sub-basin
3. Arrive at the peak flood by routing peak discharges of each sub-basin through various channel reaches (apply channel routing by Muskingum method etc.)

Flood frequency studies

The values of the annual maximum flood from a given catchment area for a large number of successive years constitute a hydrologic data series called **annual series**.

If the data are arranged in decreasing order of magnitude, the probability P of each event being equalled or exceeded is calculated by the **plotting position formula (Weibull method)** given as

$$P = \frac{m}{n+1} \qquad \mathbf{T} = \frac{\mathbf{1}}{\mathbf{P}}$$

where T is the recurrence interval or return period or frequency, m is the rank in the descending order and n is the number of years of record

Other plotting position formulae

California method $P = \frac{m}{n}$

Hazen method $P = \frac{2m - 1}{2n}$

Gumbel method $P = \frac{m + c - 1}{n}$

Gumbel's c values

C	1	0.88	0.845	0.78	0.73	0.66	0.59	0.52	0.40	0.38	0.28
m/n	1	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.08	0.04

Gumbel's method

$$P(Q \geq Q_o) = 1 - e^{-e^{-y}}$$

Q = peak flood

y is a dimensionless variable given by

$$y = \alpha(Q - a)$$

$$a = \overline{Q} - 0.45005\sigma_Q$$

$$\alpha = 1.2825/\sigma_Q$$

$\overline{Q}$ = mean and σ_Q = standard deviation of variable Q

Substituting α and a, we get

$$y = \frac{1.2825}{\sigma_Q}(Q - \overline{Q}) + 0.577$$

$$y = \frac{1.2825}{\sigma_Q}(Q - \overline{Q}) + 0.577$$

Writing in the general form of the flood frequency equation as suggested by V.T.Chow (1954)

$$Q_T (= Q) = \overline{Q} + K\sigma_Q$$

K= flood frequency factor which depends on the return period and the assumed frequency distribution

$$K = \frac{y_T - 0.577}{1.2825}$$

$$P = 1 - e^{-e^{-y}}$$

Taking natural logarithm of the both sides of the equation

$$y = -\ln[-\ln(1 - P)]$$

since, T=1/P, we get

$$y(= y_P = y_T) = -[\ln\ln \frac{T}{T-1}]$$

Practical application of the Gumbel's equation for finite sample size

$$Q_T = \overline{Q} + K\sigma_{n-1}$$

where

$$\sigma_{n-1} = \sqrt{\frac{\sum (Q-\overline{Q})^2}{n-1}}$$

$$K = \frac{y_T - \overline{y}_n}{s_n}$$

$\overline{y}_n$ =reduced mean, a function of the sample size n

s_n=reduced standard deviation, a function of the sample size n

$$(n \to \infty, \overline{y}_n \to 0.577, s_n \to 1.2825)$$

Reduced mean and reduced standard deviation for Gumbel's method in finite sample size

N = sample size

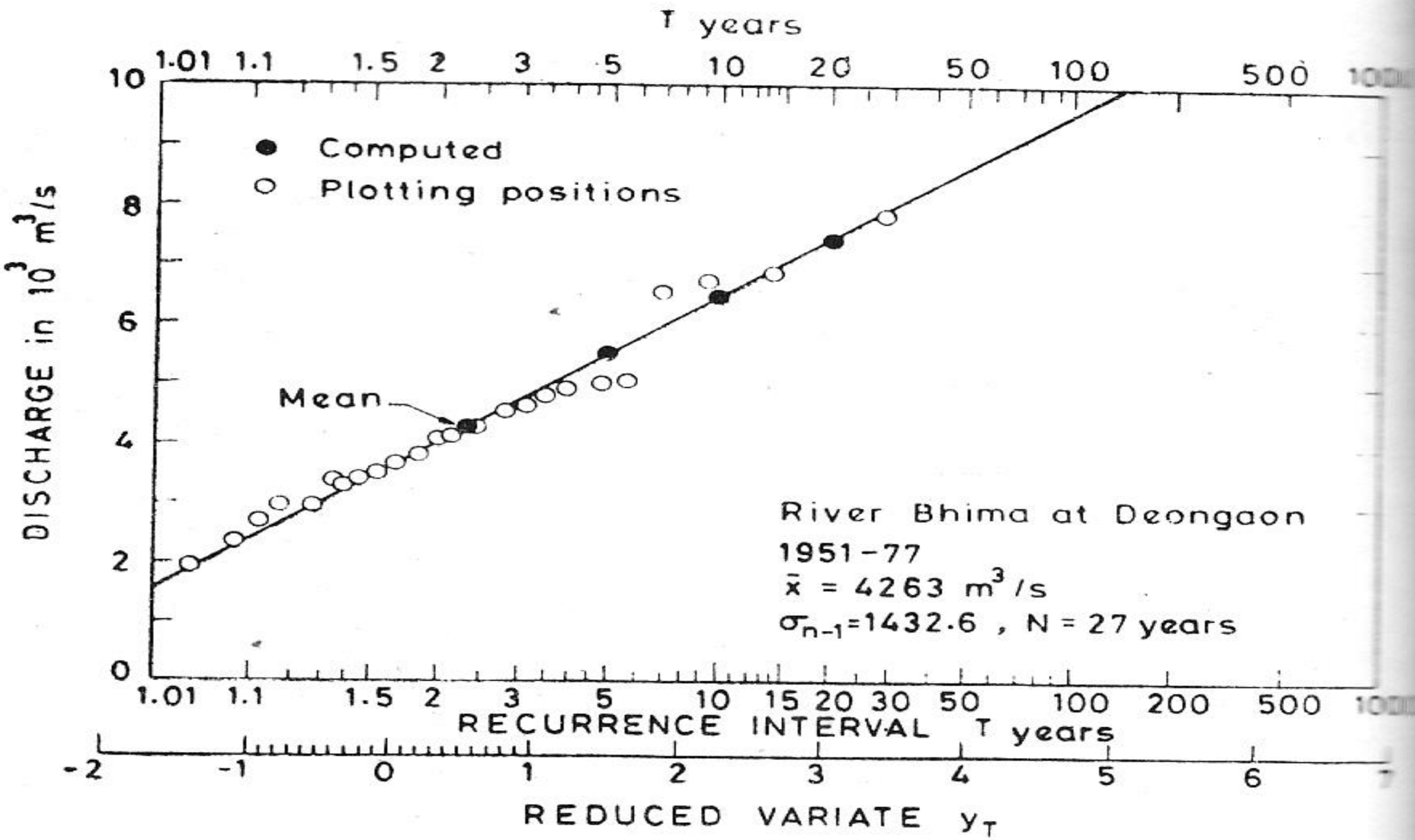
N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5320	0.5332 (N=27)	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5410	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

REDUCED STANDARD DEVIATION s_n IN GUMBEL'S EXTREME VALUE DISTRIBUTION

N = sample size

N	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9676	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.0915	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.1480	1.1499	1.1519	1.1538	1.1557	1.1574	1.1590
50	1.1607	1.1623	1.1638	1.1658	1.1667	1.1681	1.1696	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1906	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1959	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	→ 1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

Flood estimation by plotting position formula and Gumbel's method



Flood probability analysis by Gumbel's distribution

Ven Te Chow method

$$Q_T = a + bX_T, \qquad X_T = \log\log\frac{T}{T-1}$$

a and b are parameters to be estimated by the method of moments from the observed data

Using the method of least squares, following equations can be derived:

$$\sum Q = an + b\sum X_T$$

$$\sum(QX_T) = a\sum X_T + b\sum(X_T^2)$$

Solve the above equations

If in the hydrologic data seies, QT has a rank m, its plotting position is T=(n+1)/m

Powell method

$$Q_T = \bar{Q} + K\sigma$$

$$K = \frac{\sqrt{6}}{\pi}\left[\gamma + \ln\ln\frac{T}{T-1}\right]$$

γ = Euler's constant = 0.5772

K =-1.1-1.975XT, where $X_T = \log\log\frac{T}{T-1}$

Log Pearson Type III Distribution

If Q is the variate of a random hydrologic series, then

$$Z = \log Q$$

$$Z_T = \overline{Z} + K_z \sigma_z$$

K_z = a frequency factor which is a function of the recurrence interval (T) and coefficient of skew (C_s)

$K_z = f(C_s, T)$

$$\sigma_z = \sqrt{\frac{\sum (Z - \overline{Z})^2}{n - 1}}$$

$$C_s = \frac{n \sum (Z - \overline{Z})^3}{(n-1)(n-2)(\sigma_z)^3}$$

after finding Z_T, find peak flood as

Q_T=antilog(Z_T)

To account for the **finite sample size**, coefficient of skew is adjusted as:

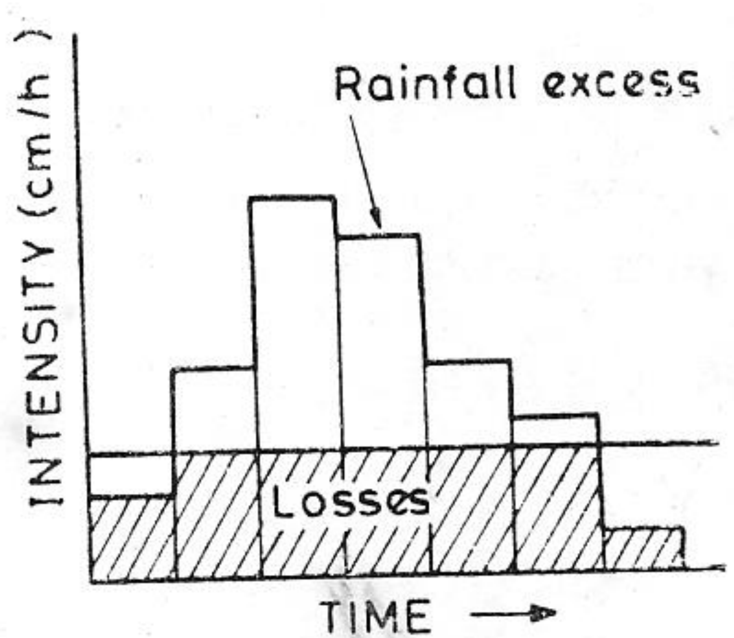
$$\hat{C}_S = C_S\left(1 + \frac{8.5}{n}\right)$$

Coefficient of skew for various sample sizes

$K_z = f(C_s, T)$ FOR USE IN LOG-PEARSON TYPE III DISTRIBUTION

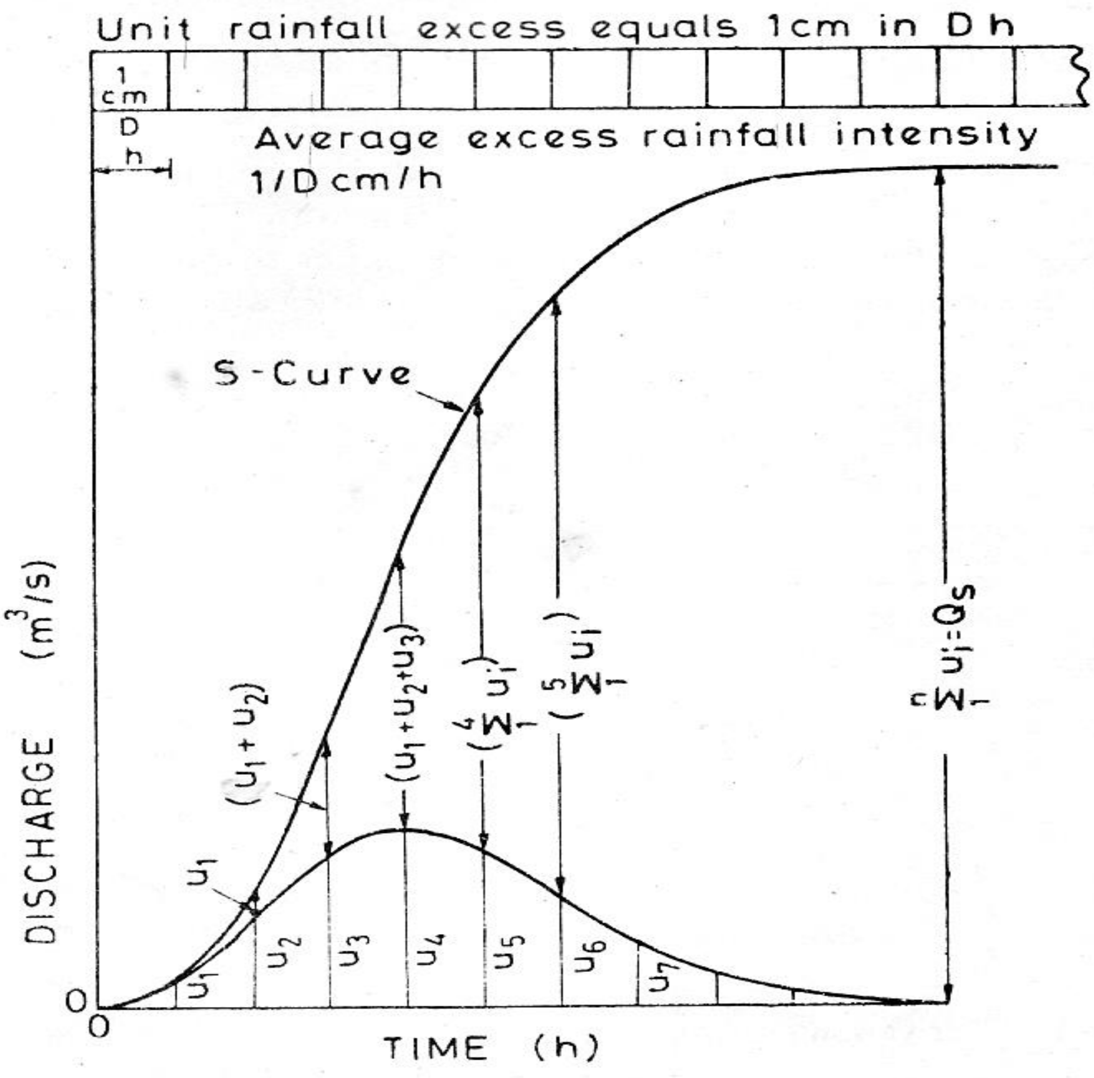
Coefficient of skew, C_s	Recurrence interval T in years						
	2	10	25	50	100	200	[illegible]
3.0	−0.396	1.180	2.278	3.152	4.051	4.970	[illegible]
2.5	−0.360	1.250	2.262	3.048	3.845	4.652	[illegible]
2.2	−0.330	1.284	2.240	2.970	3.705	4.444	[illegible]
2.0	−0.307	1.302	2.219	2.912	3.605	4.298	[illegible]
1.8	−0.282	1.318	2.193	2.848	3.499	4.147	[illegible]
1.6	−0.254	1.329	2.163	2.780	3.388	3.990	[illegible]
1.4	−0.225	1.337	2.128	2.706	3.271	3.828	[illegible]
1.2	−0.195	1.340	2.087	2.626	3.149	3.661	[illegible]
1.0	−0.164	1.340	2.043	2.542	3.022	3.489	[illegible]
0.9	−0.148	1.339	2.018	2.498	2.957	3.401	[illegible]
0.8	−0.132	1.336	1.998	2.453	2.891	3.312	[illegible]
0.7	−0.116	1.333	1.967	2.407	2.824	3.223	[illegible]
0.6	−0.099	1.328	1.939	2.359	2.755	3.132	[illegible]
0.5	−0.083	1.323	1.910	2.311	2.686	3.041	[illegible]
0.4	−0.066	1.317	1.880	2.261	2.615	2.949	[illegible]
0.3	−0.050	1.309	1.849	2.211	2.544	2.856	[illegible]
0.2	−0.033	1.301	1.818	2.159	2.472	2.763	[illegible]
0.1	−0.017	1.292	1.785	2.107	2.400	2.670	[illegible]
0.0	0.000	1.282	1.751	2.054	2.326	2.576	[illegible]
−0.1	0.017	1.270	1.716	2.000	2.252	2.482	[illegible]
−0.2	0.033	1.258	1.680	1.945	2.178	2.388	[illegible]
−0.3	0.050	1.245	1.643	1.890	2.104	2.294	[illegible]
−0.4	0.066	1.231	1.606	1.834	2.029	2.201	[illegible]
−0.5	0.083	1.216	1.567	1.777	1.955	2.108	[illegible]
−0.6	0.099	1.200	1.528	1.720	1.880	2.016	[illegible]
−0.7	0.116	1.183	1.488	1.663	1.806	1.926	[illegible]
−0.8	0.132	1.166	1.448	1.606	1.733	1.837	[illegible]
−0.9	0.148	1.147	1.407	1.549	1.660	1.749	[illegible]
−1.0	0.164	1.128	1.366	1.492	1.588	1.664	[illegible]
−1.4	0.225	1.041	1.198	1.270	1.318	1.351	[illegible]
−1.8	0.282	0.945	1.035	1.069	1.087	1.097	[illegible]
−2.2	0.330	0.844	0.888	0.900	0.905	0.907	[illegible]
−3.0	0.396	0.660	0.666	0.666	0.667	0.667	[illegible]

Estimation of the rainfall excess



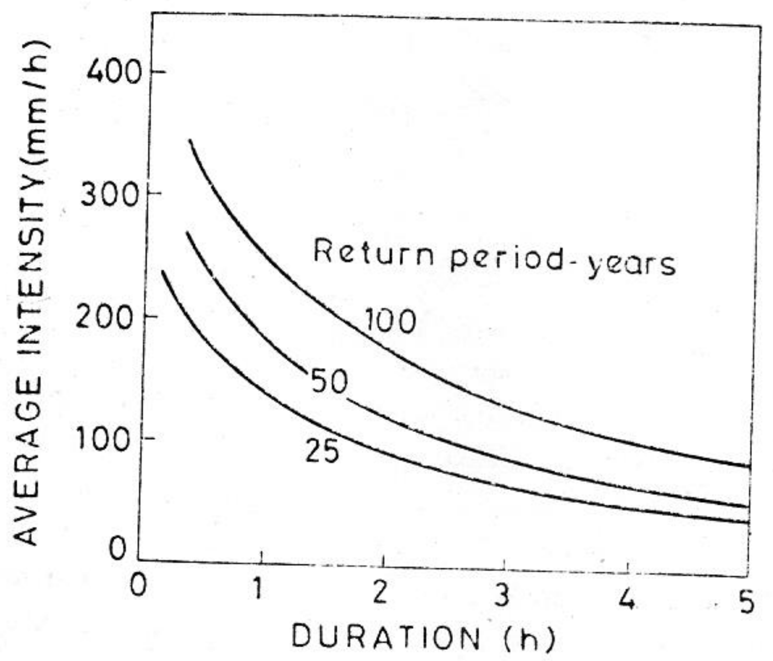
Effective rainfall hyetograph

Summation of unit hydrographs for determining S curve



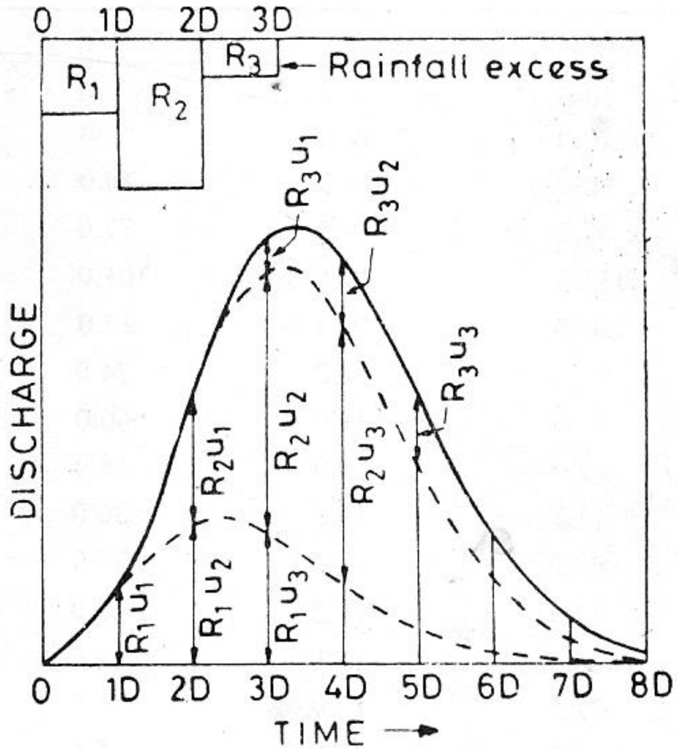
S-curve

Determination of the rainfall intensity



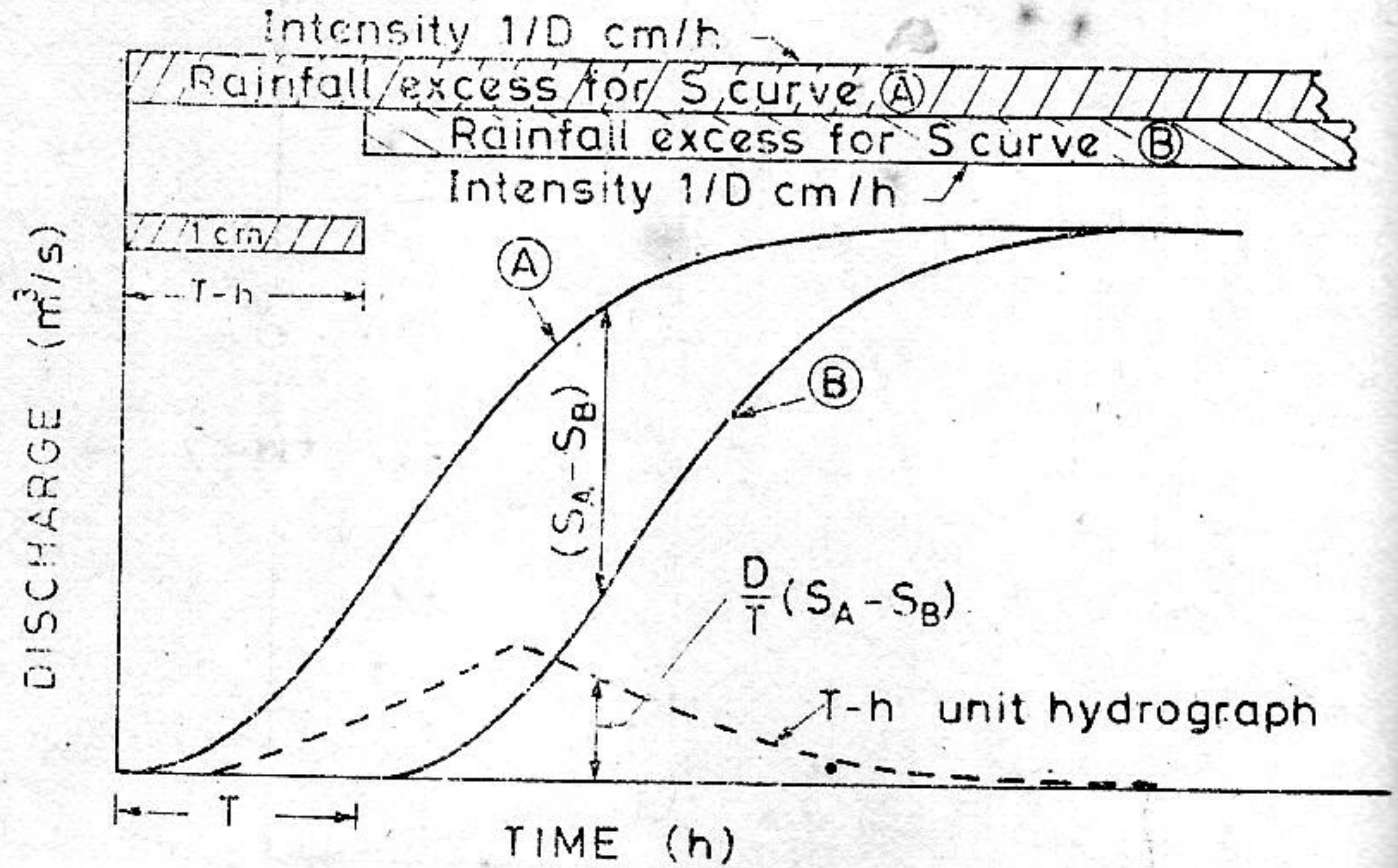
Intensity–duration–frequency curves

Determination of the composite hydrograph for a complex storm



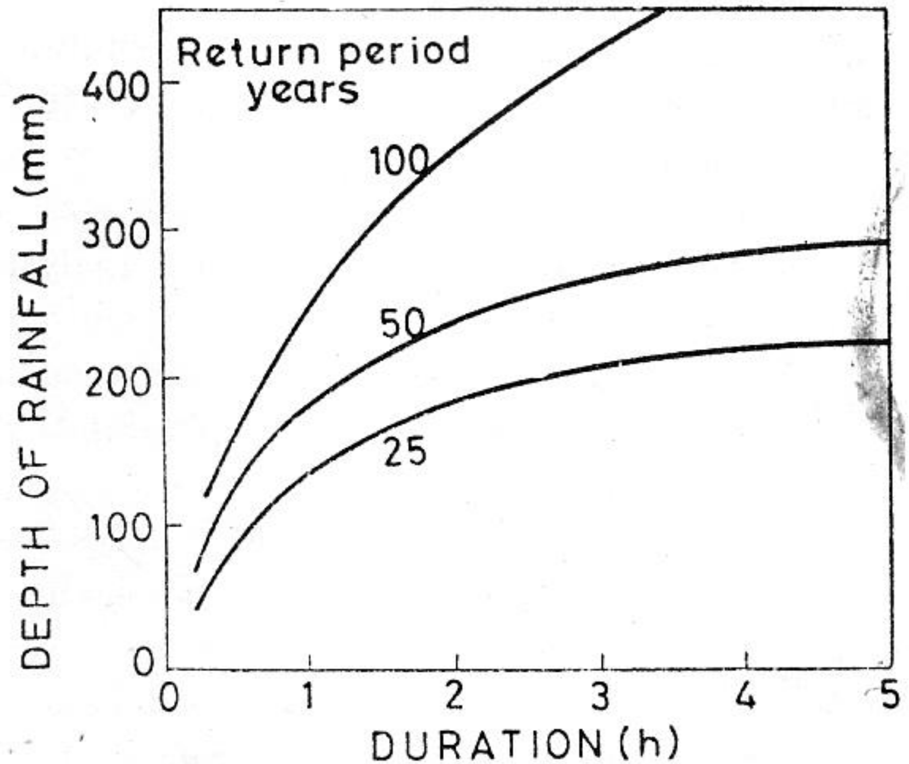
Unit hydrograph from a complex storm

Determination of T-hr UH from S-curves



Derivation of a *T*-h unit hydrograph by *S*-curve lagging method

Rainfall depth for various durations



Depth–duration–frequency curves

Thank you

Chart for visual comparison of estimated floods

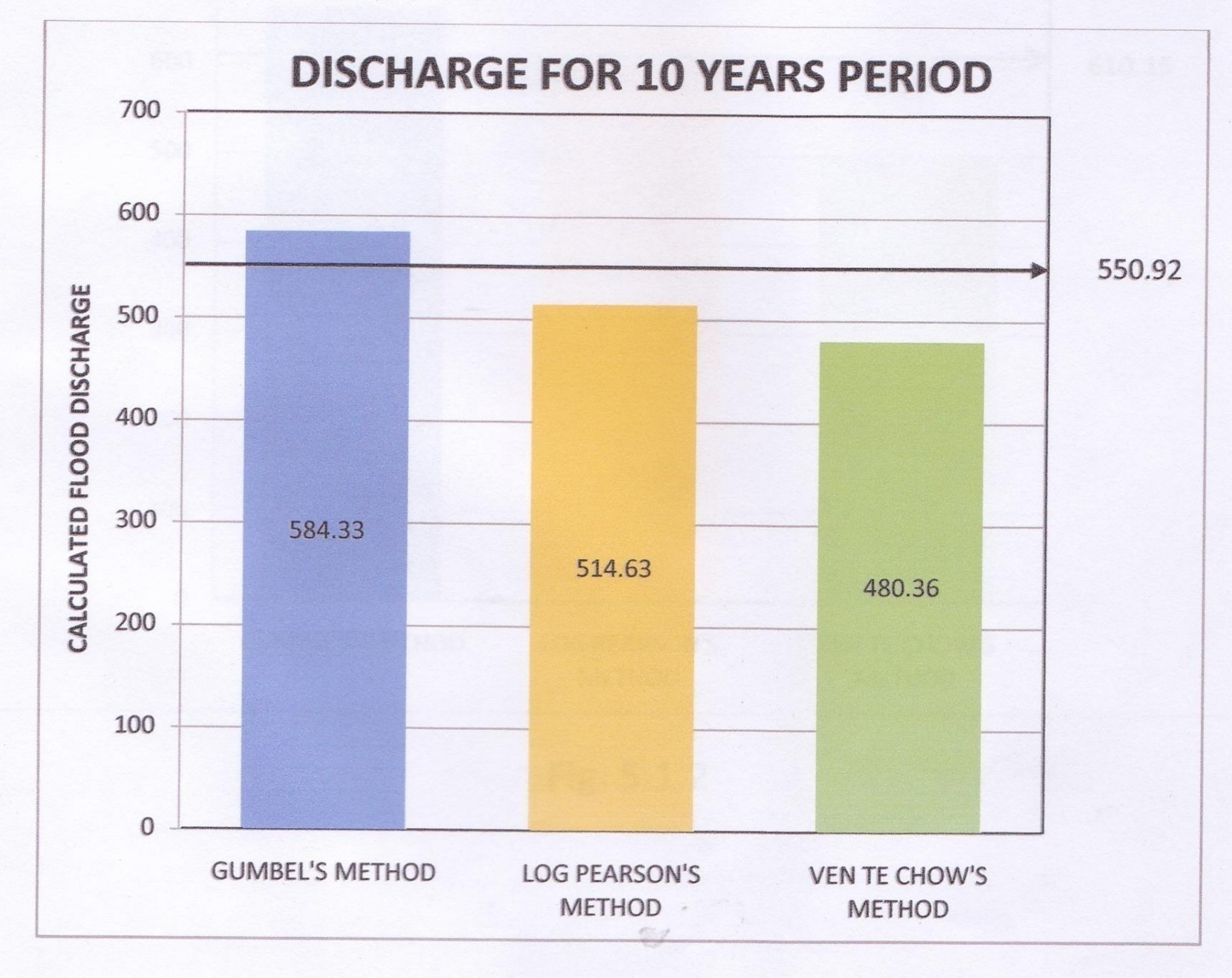


Chart for visual comparison of estimated floods

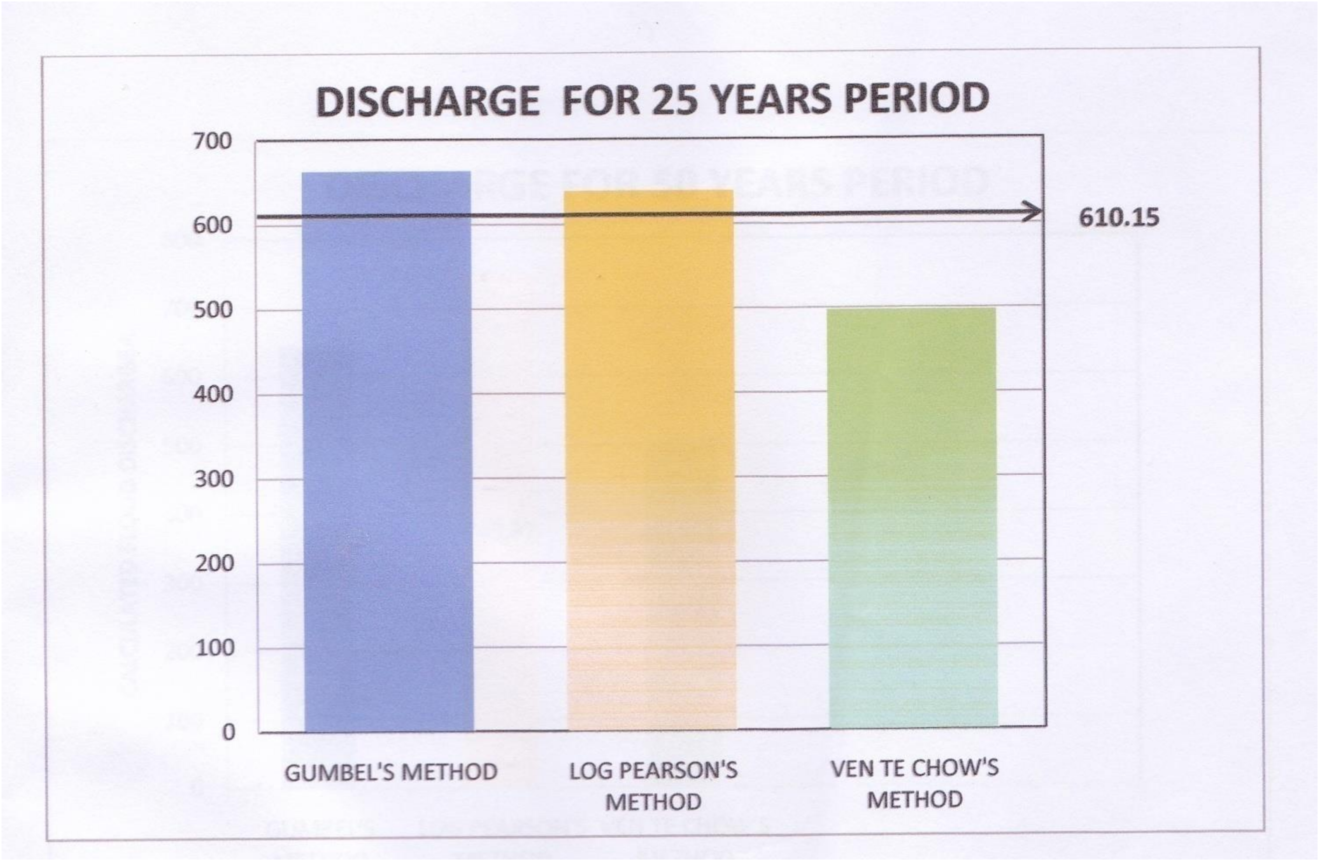
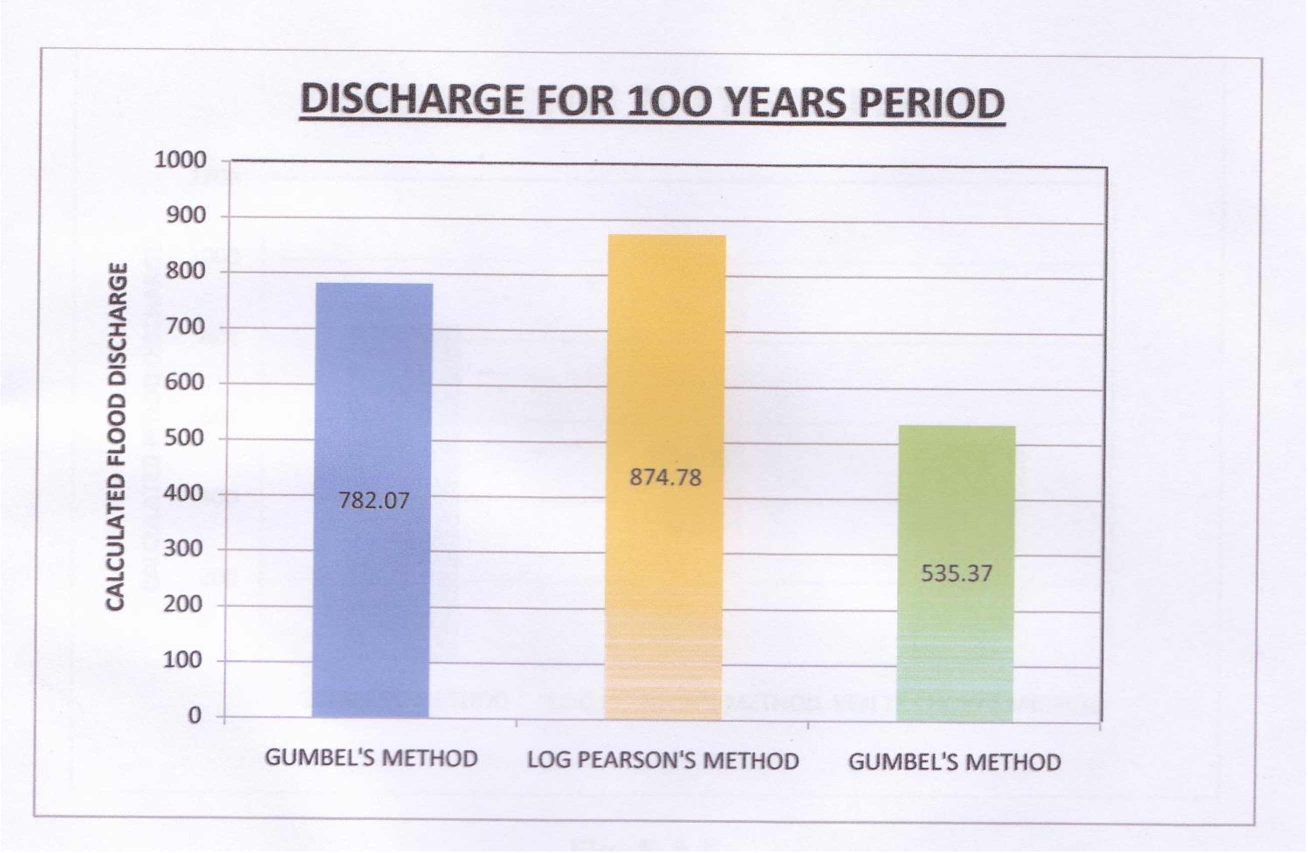


Chart for visual comparison of estimated floods



Flood photos in Dhemaji

Flood in Thailand

Lecture on Waste Mangement - Dr Pradip Baishya

Training Programme on "Construction Management"
for Town & Country Planning, Assam

Solid Waste Management

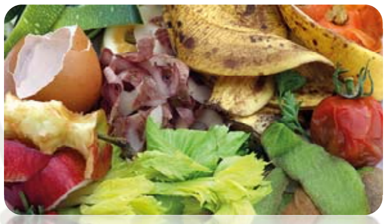
Introduction to Municipal Solid Waste

Presented by
Dr. Pradip Baishya
Assistant Professor,
Assam Engineering College
Contact: (+91)9435046680
Email: baishyapk@gmail.com

एक कदम स्वच्छता की ओर

What is Waste?

Problems from waste



- Damages the environment
- Can harm animals
- Costs lots of money
- Can be bad for your health
- Makes the neighbourhood look dirty
- Some resources are limited- when they are gone we won't have them anymore

Challenges in Waste

- Spiraling and sprawling growth of urban population all over the world the challenges Solid Waste Management faces today is huge.
- Technology available in developed countries is hard to implement in India in this sector due to funds limitation, different demographic profile of users, general education and awareness level in the community regarding waste.
- People practicing 'not in my backyard' (NIMBY) philosophy.
- Cities in developing countries hardly spend more than 0.5% of their per capita gross national productivity (GNP) on urban waste services, which covers only about one-third of overall cost (World Bank, 1999).

- Under these stringent budgets and complex problems to deal with, it is vital to devise ways which would strike a balance between the cost effectiveness and the quality of the waste management process.
- Implementation of waste management with proper segregation and supporting technologies for processing the recyclables can go a long way in minimizing the energy consumed for manufacturing.
- Urban Local Bodies spend around Rs.500/- to Rs.1500/- per ton on solid waste management, of which 60-70% is on collection, 20%-30% on transportation and minimal on treatment and disposal of waste (UNDP Report 2008).
- Open, unsorted and poorly managed land filling is commonly the practice in most cities of India as well as in Assam.

Global Waste Statistics

- Annual global generation of MSW was estimated to be 1.3 billion tonnes, and it is expected to rise to 2.2 billion tonnes per year by 2025.
- The per capita generation is projected to increase from 1.2 kg to 1.42 kg per day by 2025. The worldwide average is 1.2kg.
- Solid wastes in urban areas of East Asia alone will increase from 760,000 tonnes/day to 1.8 million tonnes/day within 25 years, while waste management costs will almost double from US$ 25 billion to US$ 47 billion by 2025 (World Bank).
- The top producers of MSW were small island nations, including
  Trinidad & Tobago (14.40 kg/capita/day),
  Antigua and Barbuda (5.5kg)
  St. Kitts and Nevis (5.45kg)
  Guyana (5.33kg)
  Kuwait (5.72kg)
  Sri Lanka (5.10kg) also scored highly.

- Top five producers in the developed world
  New Zealand (3.68kg)
  Ireland (3.58kg)
  Norway (2.80kg)
  Switzerland (2.61kg)
  United States (2.58kg)
- The countries producing the least urban waste were Ghana (0.09kg) and Uruguay (0.11kg).

Waste Statistics in India

- Urban MSW generation in India is approximately 40 million tonnes per annum and is expected to rise at an annual rate of 1.33% (EIA, 2013).
- The quantity of generated solid waste mainly depends on population and people's living standards, income level, economic growth, consumption pattern and institutional framework.
- Daily per capita generation of MSW in India ranges from about 100 g in small towns to 500 g in large towns.

- The amount of MSW generated per capita is estimated to increase at a rate of 1–1.33% annually.
- The 23 metro cities in India generates about 30,000 tonnes of wastes per day while about 50,000 tonnes are generated daily from the Class I cities.
- The solid waste characteristics reveals that in India the organic fraction of the waste makes up 40-85% of the waste (National Solid Waste Association of India, 2003) depending on income and lifestyle of the population. The production and consumption of plastic increased over 70 times between 1960 and 1995.
- Per capita generation of waste in Guwahati is between 400 to 500 grams per day (GMC data) depending on the income level group and seasonal variations. It is estimated that out of the total plastic generated from household, 60% is recyclable plastic and 40% is non-recyclable plastic.

Environmental Effects

- Spread of air and water borne diseases
- Ground water contamination
- Air pollution from bad odour, particulates, fumes and smoke from burning
- Potential risks of epidemics, malaria, rabies, plague
- Additional cost and burden on the state health system
- Global warming due to methane emissions

Environmental Effects

- Threat to valuable flora and fauna
- Loss of wetland habitats
- Depreciation in aesthetic value of places reducing real estate values
- Incidence of vermin and pests
- Increased incidents of flooding due to clogging of drains and water bodies
- Social issues due to waste scavenging community

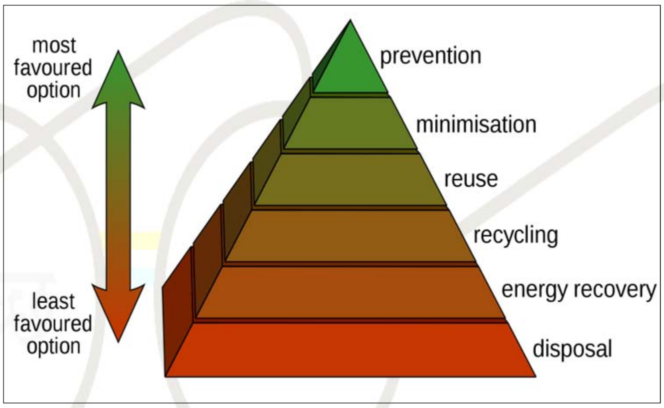


Fig. 1: Modern philosophy of waste disposal

SWM philosophy today

- Reduce
- Reuse
- Recycle
- Recovery

•The 4 R's provides an ecologically sound and environment friendly approach to minimizing and managing waste and waste streams.

•The 4 R's approach attacks a waste stream in a logical and methodical method by taking steps to sequentially Reduce, Reuse, Recycle and Recover a waste stream into incremental fractions.

Reduce Group

•Success depends on adoption of a philosophy to embrace Resource Conservation efforts.

•Responsibility for environmental sustainability in all personal and business aspects of life.

•Design for recycle strategy, not only to reduce excess or waste in the manufacturing process and packaging but to provide viable product end of life options.

•After taking steps to minimize the total waste streams we generate we can address the balance of the materials with a divide and conquer strategy. This will allow us to reduce the challenge into bite size pieces.

How Can We Reduce Waste?

In the Kitchen

- Using leftovers for other meals
- Start composting for the garden
- Recycle all your tins, cans and plastic bottles

एक कदम स्वच्छता की ओर

In the House

- Use both sides of scrap paper
- Swap & borrow toys, books & clothes rather than throwing away & buying new
- Try and buy items in packages that can be recycled
- Reuse plastic shopping bags as bin bags
- Try and buy reusable & durable items to use again & again

In the Garden

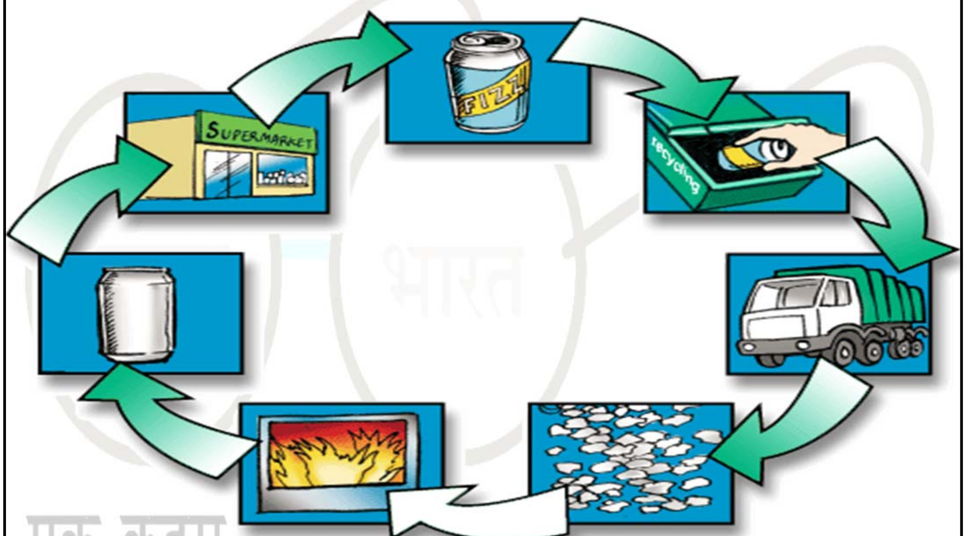
- Use a composter to deal with raw fruit, vegetable & garden waste
- Growing your own fruit and vegetables
- Reusing items found in the home for your garden e.g. CDs to keep birds from plants, plastic bottles for sapling growing

Reuse Group

- Collectables
- Repair and Refurbish
- Salvage and Dismantling
- Used Goods Retail/Wholesale

•Spanning from Collectables & antiques to general used goods retail and wholesale.
•Dealing in secondhand items typically involves the salvage of used items and may dismantling into components.
•Beyond salvage and to enhance reuse the include repair and refurbish, remanufacturing.

Recycling –integral part of zero waste philosophy



Recycle Group

- Collection
- Processing
- Sorting
- Trading
- Waste Recycling Tips

•Traditional recycling industry has been primarily a scrap commodity trading (buying and selling) operation with the major efforts focused around the costs and efficiency of freight and material handling.

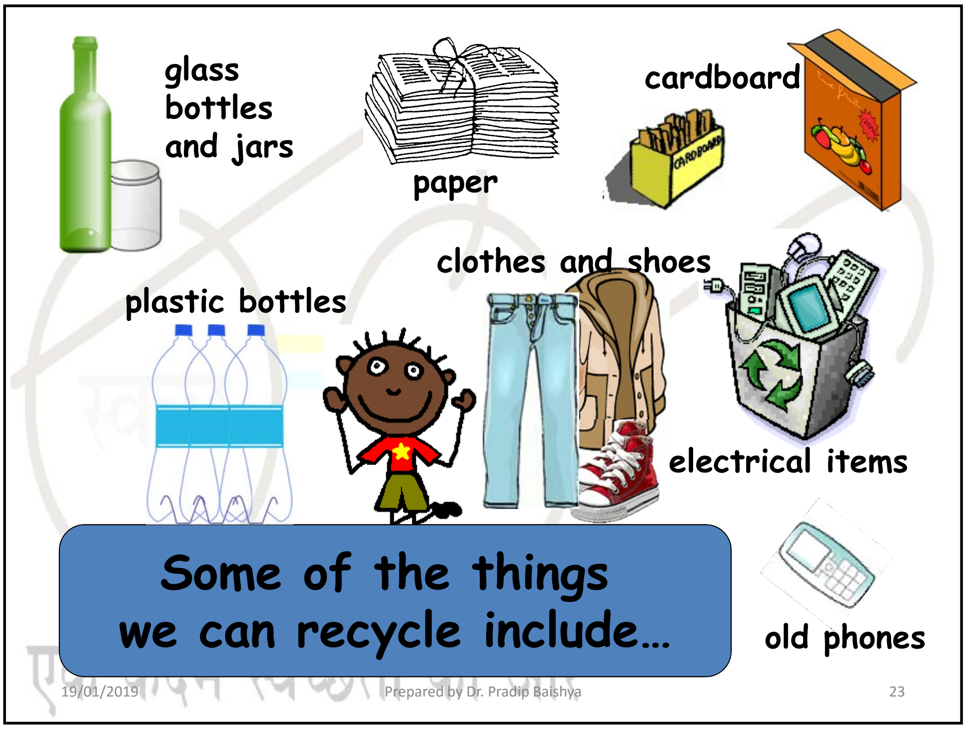
•Today's recycling industry has evolved largely into a service industry involved in the collection, sorting, processing and transportation of waste streams and by-products.

•Recycling efforts collection and sorting of recyclable materials

Recycling is a way of making sure that waste that still is usefully can be separated and reused

Recycling is important & here is why:

1. We can reuse valuable materials which are in limited supply & would be otherwise lost
2. Recycling avoids the landfill which contributes to global Climate Change
3. Saves Energy
4. Saves money



Recycling facts

- 1 recycled tin can would save enough energy to power a television for 3 hours.
- 1 recycled glass bottle would save enough energy to power a computer for 25 minutes.
- 1 recycled plastic bottle would save enough energy to power a 60-watt light bulb for 3 hours.
- 70% less energy is required to recycle paper compared with making it from raw materials
- It takes 24 trees and 4 ton of coal to make 1 ton of newspaper

Recover Group

- Commodity Residues
- Compost
- Digestion
- Incineration
- Pyrolysis & Gasification

•Conversion of waste materials for the recovery of the energy values contained within the waste material.

•Complex or mixed materials that cannot easily be recycled back into the raw commodity may be RECOVERED for their energy values.

•Recovery may be achieved through waste stream management by identifying and diverting materials from disposal into the RECOVER stream.

Advanced barriers to Recycling today

- Emphasis moved from ‘recycle more things more often’ to ‘effective recycling for quality recyclate’.
- Degree of public confusion over plastics.
- For food there are material specific barriers and attitudinal barriers .
- Different kinds of houses / buildings, each with very particular set of barriers.
- The household, not the individual, is the basic behavioural unit.

Communication on waste

- Communication on waste and recycling issues is a wide-ranging topic.
- It covers new waste strategies, new waste facilities, landfills, incinerators and materials recovery facilities (MRFs).
- Also involves encouragement of waste prevention, reuse and recycling.
- Each category can involve a different audience, different communication objectives and different communication approaches.

Effects of poor waste management

- Poor health and sanitation, more diseases..hence more cost to the national or state health system..poor workforce performance.
- Ecological degradation, hence more cost to restore the environment.
- Degradation of the image of a place, hence depreciation of value to properties and assets.
- Place becomes less attractive for migration of skilled workforce to move from better areas.

Environmental concerns

What happens when we dump waste ?
How long does it take to break down ?

- Plastic bottle: 450 years
- Plastic bags : 500 years
- Aluminium can : 200 – 800 years
- Disposable diapers : 1000 years
- Styrofoam cup : 500 years to forever
- Glass bottle : 1 million years

Environmental concerns

- Water pollution, ground water contamination
- Water logging, flooding due to clogging of drains
- Threat to valuable flora and fauna, soil
- Pollutants and toxins enter the food chain
- Health hazard for the community
- Increase in green house gas emissions
- Pollutes precious water bodies, ecology
- Damages the aesthetics of a place

What can we do

- Reduce : Behaviour change in our consumption patters as an individual . Think before we buy..do we really need
- Reuse : Can we reuse what we have..by repairing, sharing or swapping
- Recycle: Recycle as much as we can from our waste..segregate into future streams for processing

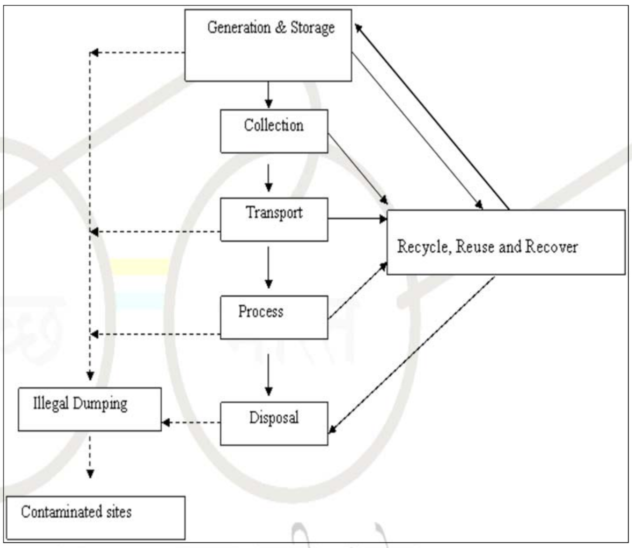
Thank you

Training Programme on “Construction Management” for Town & Country Planning, Assam

Solid Waste Management

Components of Municipal Solid Waste Management

Presented by
Dr. Pradip Baishya
Assistant Professor,
Assam Engineering College
Contact: (+91)9435046680
Email: baishyapk@gmail.com



Municipal Solid Waste Stream

Waste Segregation

- Biodegradable and non biodegradable waste needs to be segregated at source.
- Main bottleneck of MSW management.
- Saves undue effort on transportation and disposal of recyclables.
- Segregation is one of the most important mandate in SWM rules, 2016.

- No. of receptacles
- Design of receptacles
- Cost and affordability
- Cost Sharing
- Information and awareness mechanism on segregation
- Assessment of Success rate
- Measures to tackle failures & bottlenecks
- Incentives & Enforcement measures for effective segregation
- Guidelines & principles of segregation
- Identification of local challenges for adopting segregation

एक कदम स्वच्छता की ओर

Segregation receptacles

At residential developments

Information on segregation

Waste Collection Process

- Existing facilities in place for collection of waste
- Operational issues to be considered for a collection system
- Training facilities required for staff and operatives of the collection system
- Current advantages of your system looking at the goals to be achieved
- End market implications of the system to be developed
- Operational issues to be considered for maximising recovery of dry and wet waste

- Communication tools required for awareness and information dissemination of the collection process
- Additional facilities required at the site for complying with the SWM guidelines
- Health and Safety equipments, guidelines, and implications for the collection process
- Risk assessment exercises for all operations and operatives in the collection system

Exercises to evaluate collection systems

- Different approaches to the collection of Recycling and Composting materials should be identified and appraisals conducted.
- Collection systems for houses, flats, commercial establishments, institutions should be assessed in terms of operational implications.
- Assessment and evaluation of different collection systems should be done in terms of their performance for different types of materials, different quantities of materials.
- Assessment and evaluation of the segregation, sorting and quality requirements for materials to be collected.
- Assessment and evaluation of the aspects effecting the collection system in terms of system design, demography of the area, topography of collection area.

- Design and setting up disposal and facilities for community common places, town centres, places of high importance, places with high human traffic.
- Assessment of the socio-economic factors affecting the collection process and output
- Designing of collection receptacles, schedule, frequency, route maps and logistics.
- Designing of bulky collection systems for the area
- Set up of a reporting system for complaints and missed collections for all waste producers
- Set up system to tackle contamination of segregated waste, reporting and reduction

Transportation of waste

- Amount of waste to be transported
- Type of waste to be handled
- For door to door transportation of waste

  Auto tipper with separate compartments

  E rickshaw with separate compartments

  Cycle rickshaw with four bin system

  Hand cart with four bin system

एक कदम स्वच्छता की ओर

- For transportation of waste to landfill site

  Auto tipper for short distances

  Compactor for long distances

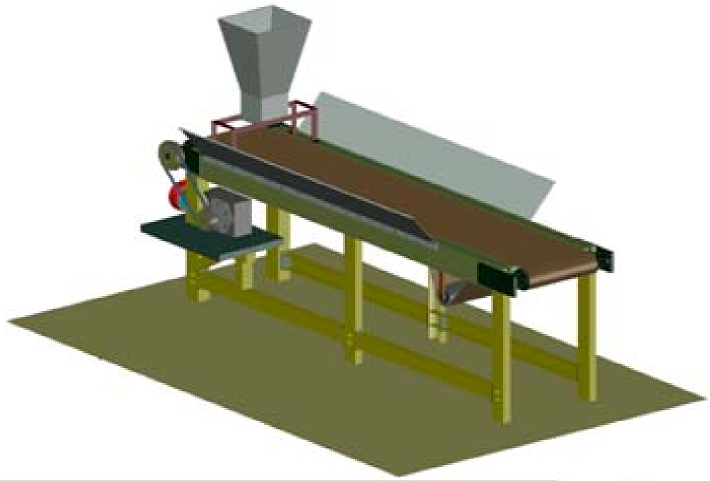
  Tipper truck with cover

स्वच्छ भारत

एक कदम स्वच्छता की ओर

Material Recovery Process

- Type of waste to be handled
- Type of sorting facility to be used
  Rotating sieve
  Semi mechanised Conveyor belt
- Quality and quantity of recyclables to be recovered
- Baler
- Dehumidifier
- Weighing apparatus
- Shredder
- Magnetic separators
- Eddy current separators



Semi mechanized belt conveyor system

Baler

Shredder

Waste recycling in UK

Introduction of recycling vans

Energy recovery process

- Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery. This process is often called waste to energy.
- Energy Recovery is an excellent method of avoiding landfill. It is safe and will not harm your community or your environment
- Converting waste into energy solves two problems at once: It diverts rubbish from landfill sites: and it reduces greenhouse gas

Refused Derived Fuel

Refuse Derived Fuel (RDF) is produced from combustible components of municipal solid waste (MSW).
The waste is shredded, dried and baled and then burned to produce electricity, thereby making good use of waste that otherwise might have ended up in landfill.

Compared to landfilling, the lower carbon emissions resulting from this approach to processing waste far outweigh the emissions associated with transporting the reclaimed fuel.

एक कदम स्वच्छता की ओर

Landfill

Should be avoided as far as possible
Last option for disposal of waste
High maintenance cost of sanitary landfills
Should not be constructed in high altitude areas
Landfill to be shared by small towns

एक कदम स्वच्छता की ओर

Sanitary landfill with Geo synthetic liner

एक कदम स्वच्छता की ओर

Municipal Solid Waste Management Rules

Presented by
Dr. Pradip Baishya
Assistant Professor,
Assam Engineering College,
Guwahati.
Contact: (+91)9435046680
Email: baishyapk@gmail.com

एक कदम स्वच्छता की ओर

- Municipal Solid Waste (Management & Handling Rules), 2000 was published in September, 2000 by the Ministry of Environment & Forests, Govt. of India.
- The rule book 2016 has also been published with amendments as discussed.
- SWM is the primary responsibility & duty of the municipal authorities.
- It includes provisions for collection, storage, segregation, transport, processing and disposal of waste.

एक कदम स्वच्छता की ओर

Salient features of SWM Rules, 2016

1. The Rules are now applicable beyond Municipal areas and extend to urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, airports, airbase, Port and harbour, defence establishments, special economic zones, State and Central government organizations, places of pilgrims, religious & historical importance.

2. The source segregation of waste has been mandated to channelize the waste to wealth by recovery, reuse and recycle.

3. Responsibilities of Generators have been introduced to segregate waste in to three streams, Wet (Biodegradable), Dry (Plastic, Paper, metal, wood, etc.) and domestic hazardous wastes (diapers, napkins, empty containers of cleaning agents, mosquito repellents, etc.) and handover segregated wastes to authorized rag-pickers or waste collectors or local bodies.

4. Integration of waste pickers/ ragpickers and waste dealers/ Kabadiwalas in the formal system should be done by State Governments, and Self Help Group, or any other group to be formed.

5. No person should throw, burn, or bury the solid waste generated by him, on streets, open public spaces outside his premises, or in the drain, or water bodies.

एक कदम स्वच्छता की ओर

6. Generator will have to pay 'User Fee' to waste collector and for 'Spot Fine' for Littering and Non-segregation.

7. Used sanitary waste like diapers, sanitary pads should be wrapped securely in pouches provided by manufacturers or brand owners of these products or in a suitable wrapping material and shall place the same in the bin meant for dry waste / non- bio-degradable waste.

8. The concept of partnership in Swachh Bharat has been introduced. Bulk and institutional generators, market associations, event organizers and hotels and restaurants have been made directly responsible for segregation and sorting the waste and manage in partnership with local bodies.

9. All hotels and restaurants should segregate biodegradable waste and set up a system of collection or follow the system of collection set up by local body to ensure that such food waste is utilized for composting / biomethanation.

10. All Resident Welfare and market Associations, Gated communities and institution with an area >5,000 sq. m should segregate waste at source- in to valuable dry waste like plastic, tin, glass, paper, etc. and handover recyclable material to either the authorized waste pickers or the authorized recyclers, or to the urban local body.

एक कदम स्वच्छता की ओर

11. The bio-degradable waste should be processed, treated and disposed of through composting or bio-methanation within the premises as far as possible. The residual waste shall be given to the waste collectors or agency as directed by the local authority.

12. New townships and Group Housing Societies have been made responsible to develop in-house waste handling, and processing arrangements for bio-degradable waste.

13. Every street vendor should keep suitable containers for storage of waste generated during the course of his activity such as food waste, disposable plates, cups, cans, wrappers, coconut shells, leftover food, vegetables, fruits etc. and deposit such waste at waste storage depot or container or vehicle as notified by the local authority.

14. The developers of Special Economic Zone, industrial estate, industrial park to earmark at least 5% of the total area of the plot or minimum 5 plots/ sheds for recovery and recycling facility.

15. All manufacturers of disposable products such as tin, glass, plastics packaging etc. or brand owners who introduce such products in the market shall provide necessary financial assistance to local authorities for the establishment of waste management system.

16. All such brand owners who sale or market their products in such packaging material which are non-biodegradable should put in place a system to collect back the packaging waste generated due to their production.

17. Manufacturers or Brand Owners or marketing companies of sanitary napkins and diapers should explore the possibility of using all recyclable materials in their products or they shall provide a pouch or wrapper for disposal of each napkin or diapers along with the packet of their sanitary products.

18. All such manufacturers, brand owners or marketing companies should educate the masses for wrapping and disposal of their products.

19. All industrial units using fuel and located within 100 km from a solid waste based RDF plant shall make arrangements within six months from the date of notification of these rules to replace at least 5 % of their fuel requirement by RDF so produced.

20. Non-recyclable waste having calorific value of 1500 K/cal/kg or more shall not be disposed of on landfills and shall only be utilized for generating energy either or through refuse derived fuel or by giving away as feed stock for preparing refuse derived fuel.

21. High calorific wastes shall be used for co-processing in cement or thermal power plants.

22. Construction and demolition waste should be stored, separately disposed off, as per the Construction and Demolition Waste Management Rules, 2016

23. Horticulture waste and garden waste generated from his premises should be disposed as per the directions of local authority.

24. An event, or gathering organiser of more than 100 persons at any licensed/ unlicensed place, should ensure segregation of waste at source and handing over of segregated waste to waste collector or agency, as specified by local authority.

25. Special provision for management of solid waste in hilly areas:- Construction of landfill on the hill shall be avoided. A transfer station at a suitable enclosed location shall be setup to collect residual waste from the processing facility and inert waste. Suitable land shall be identified in the plain areas, down the hill, within 25 kilometers for setting up sanitary landfill. The residual waste from the transfer station shall be disposed off at this sanitary landfill.

26. In case of non-availability of such land, efforts shall be made to set up regional sanitary landfill for the inert and residual waste.

Guidelines for Plastic waste

- Every local body shall be responsible for development and setting up of infrastructure for segregation, collection, storage, transportation, processing and disposal of the plastic waste either on its own or by engaging agencies or producers.
- The local body shall be responsible for setting up, operationalisation and co-ordination of the waste management system and for performing the associated functions, namely:-

  (a) Ensuring segregation, collection, storage, transportation, processing and disposal of plastic waste;

  (b) ensuring that no damage is caused to the environment during this process;

  (c) ensuring channelization of recyclable plastic waste fraction to recyclers;

  (d) ensuring processing and disposal on non-recyclable fraction of plastic waste in accordance with the guidelines issued by the Central Pollution Control Board;

  (e) creating awareness among all stakeholders about their responsibilities;

  (f) ensuring that open burning of plastic waste does not take place.

  (g) all plastic items to be coded with one of the following symbols

Communication

The key to change attitude, behaviour and opinion

Presented by
Dr. Pradip Baishya
Assistant Professor,
Assam Engineering College,
Guwahati.
Contact: (+91)9435046680
Email: baishyapk@gmail.com

Importance

- Tool to bring about a social change reaching different sections of the society
- Helps to understand grass root issues
- Design effective tools for information dissemination
- Aids in planning the progress of the project
- Develop strategies to spread awareness

Content

- Benefits of two way communication
- Challenges and barriers
- Behaviour and attitude change
- Developing communication material
- Planning of campaigns for awareness

Benefits of two way communication

- Marketing communication ideas around social improvement
- It empowers the people making them feel important in the process of bringing change
- Identification of issues at an early stage and address them accordingly
- Opportunity to tap local knowledge and expertise
- Reduces opposition in the community while introducing new systems
- Increases people's participation through recognition
- Increases quality of collection, materials recovery

Challenges and barriers

- Tracking positive behaviour towards segregation and recycling
- Tracking level of information dissemination
- Highlight negative behaviour towards new MSW system
- Document and compare positive versus negative behaviour
- Data assessment of behaviour towards different materials collection and recycling and its representation and segmentation

Challenges and barriers

- Situational barriers – bin facilities, receptacles, space limitations, access problems, unreliable collection process, difficult routes
- Behavioural challenges – Forgetting to segregate, busy with work, disorganised households, irregular routine in the family
- Knowledge barrier – not sure of waste segregation rules, ignorant to recycling and waste disposal rules, unsure of different bin uses
- Attitude challenges – lack of motivation towards correct waste disposal, does not believe in environmental benefits, unable to see personal gain

Developing Communication material

- Focus on local and specific benefits which stand out in value rather than vague benefits
- Focus on waste materials specifically which are in use at home or work
- Avoid too much use of feel good messages and preaching environmental benefits
- Use local examples of material transformations from waste which can be related to easily
- Relate things to economic value by quantifying

Planning of Campaigns for awareness

- List the priorities and key issues
- Campaign aims and primary objectives
- Target audiences, age groups, education level
- Type of messages in the campaign – motivational, instructional, reinforcing
- Adopted methods of the campaign – interactive, passive, tone, style, language
- Timescales of the campaign, phases
- Available resources – people, institutions, skills, budget, finance, partnerships
- Monitoring and review process

Monitoring and evaluation of campaigns

- Evaluate the cost effectiveness of different methods
- Planning of funding and budget allocation for further activities
- Accommodate continual improvement opportunities
- Qualitative as well as quantitative data analysis
- Baseline assessments to judge success
- Feedback mechanism from multiple stakeholders
- Field surveys to measure campaign impacts

Different approaches for Campaigns

- Door to door
- Television adverts
- Newspapers
- Advertisement hoardings
- Public meetings
- Leaflets
- Social Media
- Radio Adverts
- Websites
- Newsletters
- Celebrity endorsements

Different approaches for Campaigns

- Workshops
- Road shows
- Community fairs
- School visits
- Telephone helpline
- Calendars
- Bus / Taxi / Train ads
- Bin stickers
- Financial incentives
- Honorary awards
- Ads on collection vehicles

Communication material content

- To keep messages simple, effective, positive and inspirational
- Language used to be simple, clear and unambiguous
- Try to use facts and figures to motivate
- Not try to impose too much knowledge or information
- Use as little text as possible, be concise
- Use images having high impact which convey obvious messages
- Be careful when trying to make fun – can go against the purpose

19/01/2019 ip Baishya 51

Thank you

Lecture Materials - Prof Jayanta Pathak

Smart Villages Lab
Culture • Construction • Capacity • Community

Adoption of Scalable Appropriate Technology

Pradhan Mantri Awas Yojana
- Housing for All (Urban) -

Smart Villages Lab
Culture • Construction • Capacity • Community

Dr. Jayanta Pathak
Assam Engineering College

Dr. Hemanta Doloi
University of Melbourne

Contributing Members
Dr Atul Bora (Assam Engineering College)
Dr.Bipul Talukdar (Assam Engineering College)
Mr Rishiraj Borah (The University of Melbourne)

Smart Villages Lab
Culture • Construction • Capacity • Community

Mission has four components:

MoHUPA

Housing For All (Urban): Development Options

Slum Redevelopment (1)	Affordable Housing through Credit Linked Subsidy (2)	Affordable Housing in Partnership (3)	Subsidy for beneficiary-led housing (4)
"In-situ" using land as a resource with private participation Extra FSI/FAR and TDR, if required GoI grant Rs. 1 lakh per house	Subsidy for EWS and LIG for new house or incremental housing Upfront subsidy @ 6.5% for EWS and LIG for loans upto Rs. 6 lakh, calculated at NPV basis	With private sector or public sector including Parastatal agencies Central Assistance of Rs. 1.5 lakh per EWS house in projects where 35% houses for EWS category.	For individuals of EWS category for new house or enhancement Cities to prepare a separate integrated project for such beneficiaries Central assistance of Rs.1.5 lakh per beneficiary.

- Beneficiary can take advantage under one component only
- CLSS is a Central Sector Scheme, while other 3 components are to be implemented as Centrally Sponsored Schemes

3

Smart Villages Lab
Culture • Construction • Capacity • Community

MoHUPA

Technology Sub-Mission : Strategy

- Constitution of Technology Sub-Mission comprising of experts, academicians, practitioners for resolving impending issues related with technologies right from planning to execution of projects.
- Involving R&D institutions, IITs/NITs by harnessing their strength in identification, review, testing, design and consultancy in Housing Technology.
- Handholding and technical support to the States for preparation of DPR, planning & design, quality control, preparation of Schedule of Rates (SoRs), analysis of Rates, Standards and Specifications, Code of Practice, manuals and guidelines, etc.
- Capacity Building and training for State engineers, Municipal Engineers, architects, planners and artisans etc.

20

Smart Villages Lab
Culture • Construction • Capacity • Community

Technology Sub-Mission : Implementation Strategy

MoHUPA

Tier – I

Technology sub-mission headed by JS (HFA) comprising of Technical Experts and 4 States on Rotation basis. A dedicated technical cell will be set up at BMTPC to support Technology Sub-mission
The group will work under overall guidance of CSMC headed by Secretary (HUPA)
Role: Program Development

Tier – II

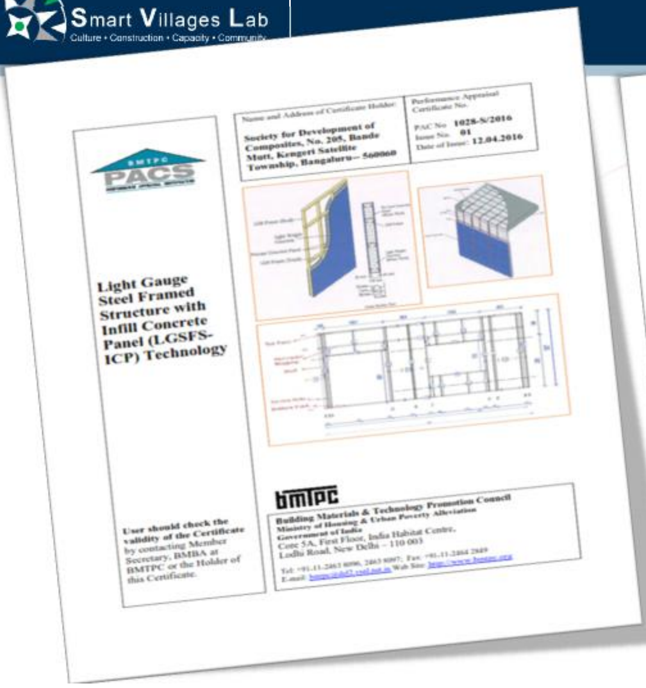
Regional Hubs represented/run by IITs/NITs in respective region (Each Hub covering 5-6 States)
Role: Overall technical support to states, comprehensive testing facilities, R&D, Training of trainers, technical vetting, preparation of manual & guidelines etc

Tier – III

IITs/NITs/ State Engg. Colleges
Role: Technical audit of DPRs, Monitoring of quality on random basis, testing Training of engineers & planners , Any other activity based on expertise available in the institute

21

Smart Villages Lab
Culture • Construction • Capacity • Community



BMTPC PACS

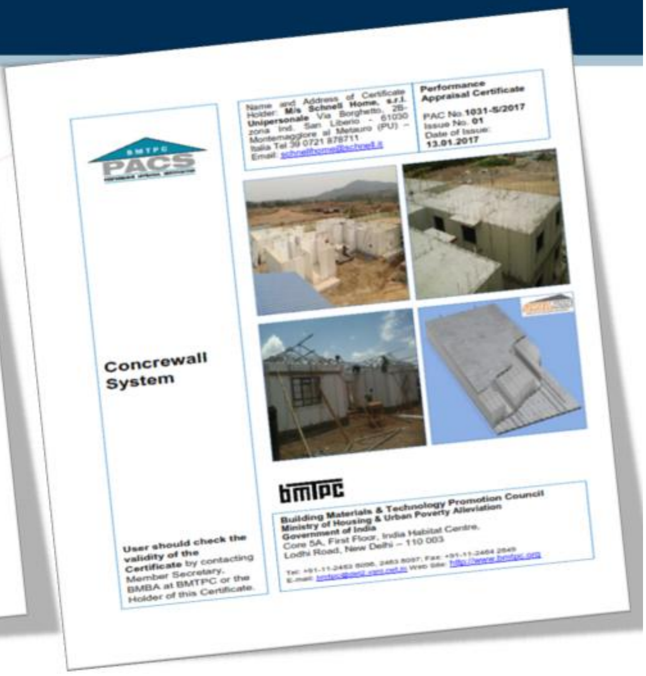
Name and Address of Certificate Holder:
Society for Development of Composites, No. 205, Bande Mutt, Kengeri Satellite Township, Bangaluru– 560060

Performance Appraisal Certificate No.
PAC No **1028-S/2016**
Issue No. **01**
Date of Issue: **12.04.2016**

Light Gauge Steel Framed Structure with Infill Concrete Panel (LGSFS-ICP) Technology

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

bmtpc
Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre,
Lodhi Road, New Delhi – 110 003



BMTPC PACS

Name and Address of Certificate Holder: **M/s Schnell Home, s.r.l. Unipersonale** Via Borghetto, 2B- zona Ind. San Liberio - 61030 Montemaggiore al Metauro (PU) – Italia Tel 39 0721 878711
Email: schnellhome@schnell.it

Performance Appraisal Certificate
PAC No.**1031-S/2017**
Issue No. **01**
Date of Issue:
13.01.2017

Concrewall System

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

bmtpc
Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre,
Lodhi Road, New Delhi – 110 003

Smart Villages Lab
Culture • Construction • Capacity • Community

PACS

Prefabricated Fibre Reinforced Sandwich Panels

Name and Address of Certificate Holder: **M/s HIL Ltd.**
SLN Terminus, 7th Floor, Near Botanical Garden, Gachibowli, Hyderabad – 500032 (Telangana)
Tel. 040- 30999185
E mail: jeyakrishnan.pk@hil.in

Performance Appraisal Certificate
PAC No. **1030-S/2017**
Issue No. **01**
Date of Issue: **13.01.2017**

bmtpc

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre, Lodhi Road, New Delhi – 110 003
Tel. +91-11-2463 8096, 2463 8097, Fax. +91-11-2464 2849
E mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

PACS

Insulating Concrete Forms

Name and Address of Certificate Holder:
M/s Reliable Insupacks (P) Ltd
B-2/7, Site B, UPSIDC Industrial Area, Surajpur, Greater Noida 201306 (UP).
Phone No. 09555201234
Email: admin@reliableinsupacks.com

Performance Appraisal Certificate
PAC No. **1029-S/2017**
Issue No. **01**
Date of Issue: **13.01.2017**

bmtpc

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre, Lodhi Road, New Delhi – 110 003
Tel: +91-11-2463 8096, 2463 8097; Fax: +91-11-2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

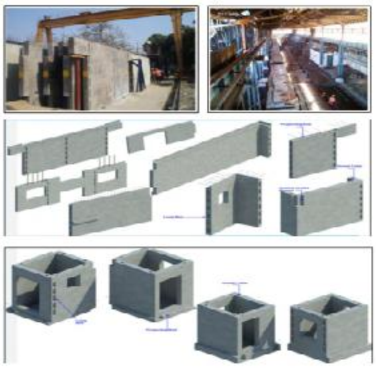
Smart Villages Lab
Culture • Construction • Capacity • Community

PACS

Precast Large Concrete Panel System

Name and Address of Certificate Holder:
M/s Larsen & Toubro Ltd.
Landmark A, 5th Floor,
Suren Road, Off Andheri Kurla Road, Andheri East,
Mumbai – 400093

Performance Appraisal Certificate No.
PAC No **1027-S/2016**
Issue No **01**
Date of Issue: **12.04.2016**



bmtpc

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

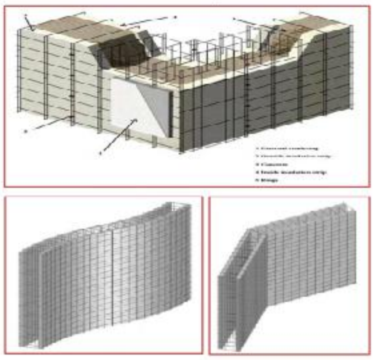
Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre, Lodhi Road, New Delhi – 110 003
Tel. +91-11-2463 8096, 2463 8097, Fax. +91-11-2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

PACS

Sismo Building Technology

Name and Address of Certificate Holder:
M/s M. K. S. Infosolutions Pvt. Ltd.
Plot No. 141, Sector 7,
IMT Manesar,
Gurgaon – 122050 (Haryana)

Performance Appraisal Certificate No.
PAC No **1025-S/2016**
Issue No. **01**
Date of Issue: **08.04.2016**



bmtpc

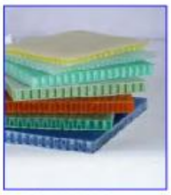
User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre, Lodhi Road, New Delhi – 110 003
Tel: +91 11 2463 8096, 2463 8097; Fax: +91 11 2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

Smart Villages Lab
Culture • Construction • Capacity • Community

BMTPC PACS PERFORMANCE APPRAISAL CERTIFICATION

Name and Address of Certificate Holder:	Performance Appraisal Certificate No.
M/s Anjani Technoplast Ltd. 6A, Sector-40/41, Ecotech-I, Greater Noida, (UP) – 201310,	PAC No 1023-P/2015 Issue No. 01 Date of Issue: 16.11.2015



Plastic Honeycomb Toilet Structures

bmtpc

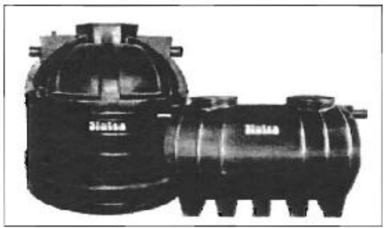
User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre,
Lodhi Road, New Delhi – 110 003

Tel: +91-11-2463 8096, 2463 8097; Fax: +91-11-2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

BMTPC PACS PERFORMANCE APPRAISAL CERTIFICATION

Name and Address of Certificate Holder	Performance Appraisal Certificate No.
M/s Sintex Industries Ltd. Kalol (N. Gujarat) – 382721 Gandhinagar, India	PAC No. 1001-C/2011 Issue No. 01 Date of Issue. 29.06.2011



Polyethylene Underground Septic Tank

bmtpc

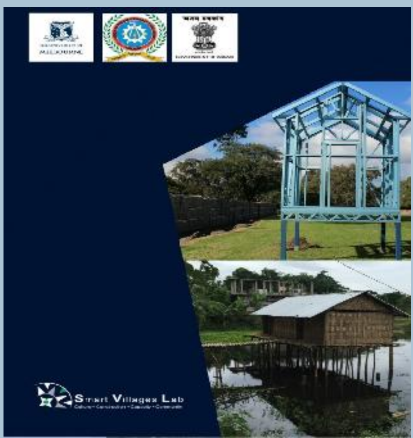
User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre,
Lodhi Road, New Delhi – 110 003

Tel: +91-11-2463 8096, 2463 8097; Fax: +91-11-2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

Smart Villages Lab
Culture • Construction • Capacity • Community

Contextualization of Experimental Building in LGS



Dr. Jayanta Pathak
Assam Engineering College

Dr. Hemanta Doloi
University of Melbourne

Contributing Members

Dr Atul Bora (Assam Engineering College)

Dr.Bipul Talukdar (Assam Engineering College)

Mr Rishiraj Borah (The University of Melbourne)

Smart Villages Lab
Culture • Construction • Capacity • Community

TECHNOLOGY PROFILE

Light Gauge Steel Framed Structures (LGSF)

Promoted under " Housing for All" – scheme Govt of India & Prime Ministers Awas Yojana
Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation, Government of India

bmtpc

- Light Gauge Steel Framed Structures (LGSF) is based on factory made galvanized light gauge steel components,
- **Designed as per codal requirements, produced by cold forming method and assembled as panels at site forming structural steel framework of a building of varying sizes of wall and floor.**
- **The basic building elements of light gauge steel framing are cold formed sections which can be prefabricated on site.**
- **LGSF is already well established in residential construction in North America, Australia and Japan and is gaining ground in India.**
- **Due to its flexibility, fast construction and durability, this technology has great potential for Assam.**
- **LGSF can be combined with composite steel / concrete deck resting on light steel framing stud walls.**
- **Apart from having potential for mass housing, modular buildings can be used for long term temporary or permanent structures such as schools and classroom, military and civil housing needs, post – disaster relief structures.**

Smart Villages Lab
Culture • Construction • Capacity • Community

Factory made – high quality – low cost

Advantage

LGSF is based on established system of light gauge steel structures and designed as per codal provisions with loading requirements as per Indian Standards.

High Precision
- Fully integrated computerised system with CNC machine provides very high accuracy upto 1 mm.

Structural
- High strength to weight ratio. Earthquake force generation is less due to light weight. Chance of progressive collapse are marginal due to highly ductile and load carrying nature of closely spaced studs/joists.

Speed in Construction
- Construction speed is very high. A typical four storeyed building can be constructed within one month.

Saving in foundation
- Structure being light, does not require heavy foundation.

Mobility
- Structural element can be transported any place including hilly places to remote places easily and structure can be erected fast.
- Structure can be shifted from one location to other without wastage of materials.

Environment friendly
- Steel used can be recycled when required.

Smart Villages Lab
Culture • Construction • Capacity • Community

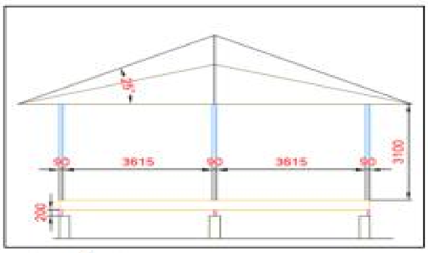
Design & Construction

Design	
	The LGSS is designed based on provision of the following standards: • Indian Standard IS 801: 1975 Code of Practices for use of cold formed and welded section and light gauge steel structural members in general building construction. • British Standard BS 5950 (Part 5):1998 – Structural use of steel in Building Part 5 – Code of Practice for design of cold formed thin gauge structure. • British Standard BS 5950 (Part 1): 2000 Structure use of steel work in Building Part 1 with loading requirement as per IS 875 (Part 1) • Indian Standard IS 875 : 1987 Code of Practice for design loads Part 1 - Dead Loads - Unit Weights of Building Material and Stored Materials Part 2 - Imposed Loads Part 3 - Wind Loads • IS 1893 (Part 1):2002 Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings
Manufacturing	
	The sectional are manufactured using a Centrally Numerical Control (CNC) automatic four Pinnacle Roll Forming machine having production speed of 450-900 m/h with very high precision.

Smart Villages Lab
Culture • Construction • Capacity • Community

Experimental Building at Majuli Assam Project

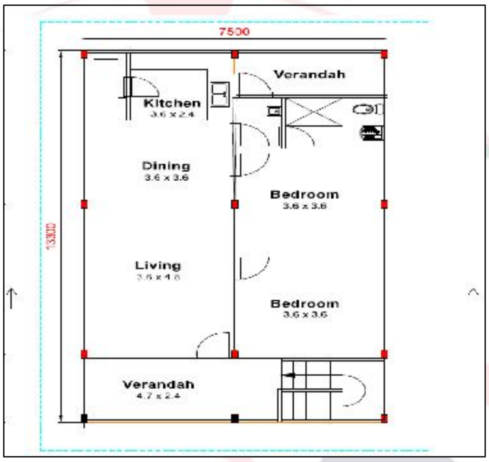
University of Melbourne – Assam Engineering College



Section

ISSUES to ADDRESS

- STRUCTURAL DESIGN
- ENCLOSURE VARIETY
- COMFORT FACTORS IN LGS SYSTEMS
- SERVICES INTEGRATION
- TRAINED MAN POWER
- MINDSET MANAGEMENT
- AFTER SALE SERVICES
- INTEGRATION IN THE SOCIAL AND CULTURAL BACK DROP

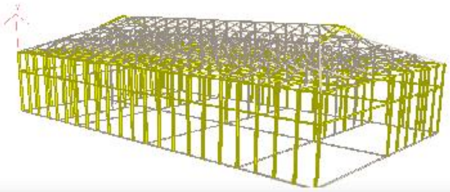


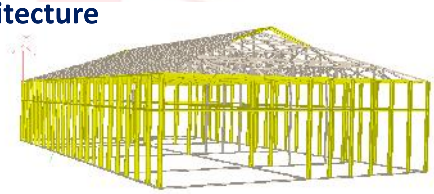
Plan

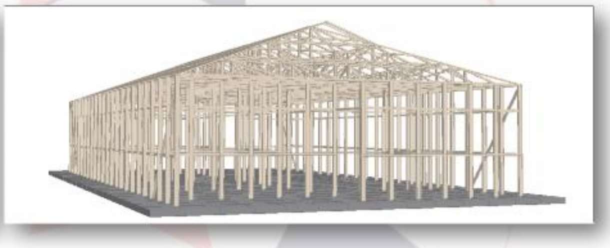
Culture • Construction • Capacity • Community

The LGSF Model for Majuli Experimental Building

The Form contextualized to match traditional Assam Type Architecture





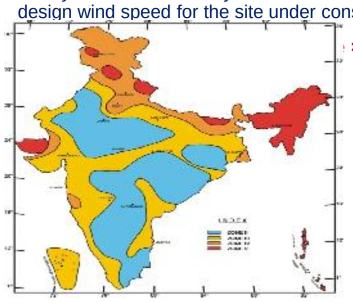


Culture • Construction • Capacity • Community

Experimental Building at Majuli Assam Project

University of Melbourne – Assam Engineering College

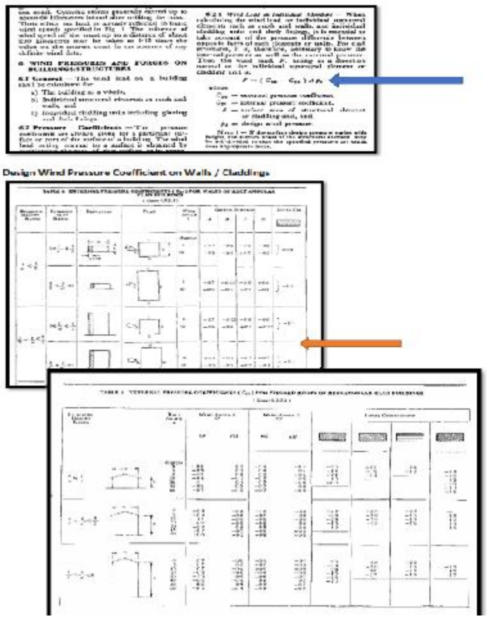
- **Guidelines for safe & Sustainable Design Building considering the location at Majuli, Assam**
- The Building should be Earthquake Resistant (Ref. **Indian Code IS:1893-2002/2016**)
- The Design Input parameters for Earthquake (Seismic) and Wind (Cyclonic) are provided below
- **Maximum Ground acceleration = 0.36g for MCE (Maximum Considered Earthquake) Magnitude 8.0 and above**
- Maximum Ground acceleration = 0.18g for DBE (Design Basis Earthquake)
- **Guidelines for the <u>Wind Load</u> calculations in the Building considering the location at Majuli Assam**
- The Building should be Wind Resistant (Ref. **Indian Code IS:875-1897/2003**)
- Ideally the wind force may be calculated on the claddings/ walls and the roof (both suction and normal pressure) from the basic wind speed -> design wind speed for the site under consideration
- **= 50 m/**

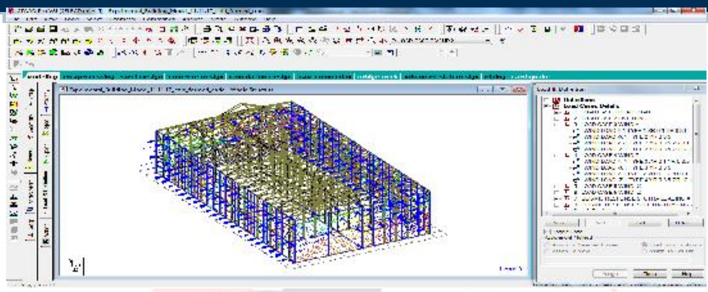


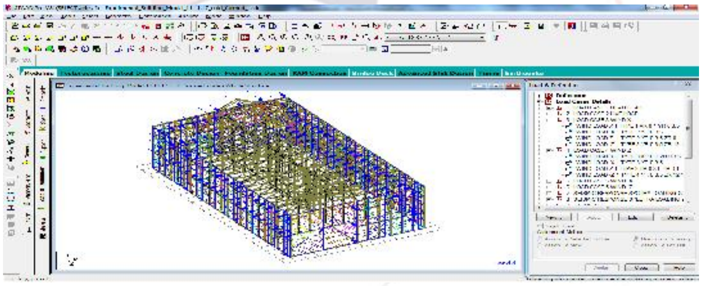
Earthquake Zone V

Smart Villages Lab
Culture • Construction • Capacity • Community

Design for Wind / Cyclone

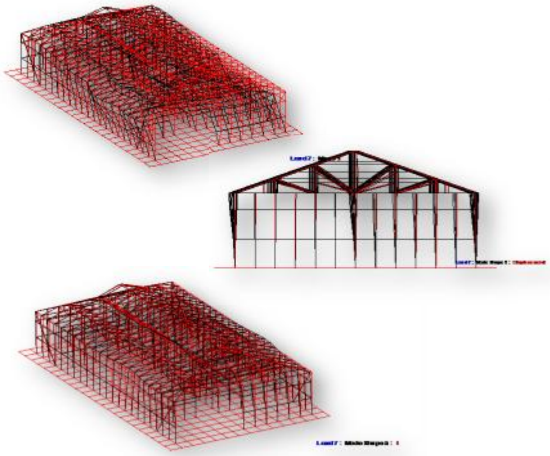






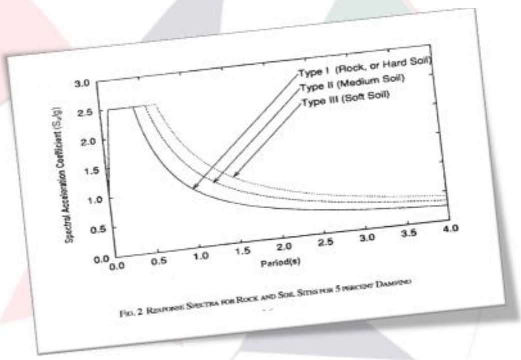
Smart Villages Lab
Culture • Construction • Capacity • Community

Design for Earthquake



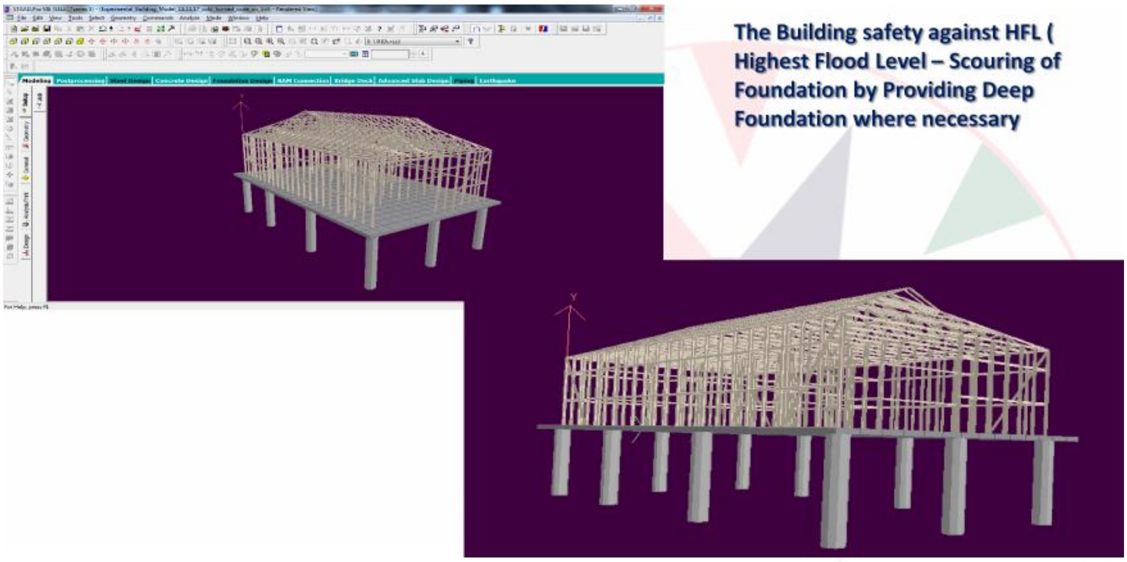
The Building safety against maximum simulated Earthquake is analysed as per Indian Standard Earthquake Code

Dynamic Analysis carried out for safety of the building using Indian code Response Spectra



Smart Villages Lab
Culture • Construction • Capacity • Community

Design for Flood



The Building safety against HFL (Highest Flood Level – Scouring of Foundation by Providing Deep Foundation where necessary

Smart Villages Lab
Culture • Construction • Capacity • Community

Cold formed Section design Optimization as per Indian Cold formed Code IS:801

STEEL TAKE-OFF

SECTION PROFILE	LENGTH(METE)	WEIGHT(MTON)
ST 60CU30X1.6	536.14	0.766
ST 80CU50X2	287.20	0.776
ST 70CU30X1.6	206.31	0.321
ST 30CU30X1.6	6.60	0.007
ST 25CU25X1.6	1.40	0.001
ST 25CU25X2	0.70	0.001
ST 90CU40X1.6	238.03	0.489
ST 40CU40X1.6	6.00	0.009
ST 20CU20X1.25	2.10	0.001

Total Requirement of Light Gauge Steel including connection etc.

= 3 Mton approx

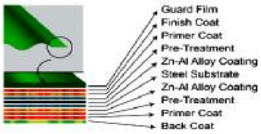
In floor metal decking

= 0.25 Mton approx

Smart Villages Lab
Culture • Construction • Capacity • Community

Proposed Roofing System
Colour Coated Galvalume Steel Sheet

Substrate Material :	Aluminum and Zinc alloy coating with steel base. (55% Al, 43.5% Zn and 1.5% Silicon)
Alloy Coating :	AZ 150 or AZ 100.
Yield Strength :	Minimum 550mpa.
Thickness :	0.40 mm - 0.80 mm
Standards : Paint System :	As per ASTM A792 / A792M & AS 1397 RMP / SMP
Characteristics :	Top Coat : 18-20 micron
Primer Top Coat :	5-7 micron
Back Coat :	6-8 micron
Primer back Coat :	3-4 micron



Environment Friendly – Locally available

Smart Villages Lab
Culture • Construction • Capacity • Community

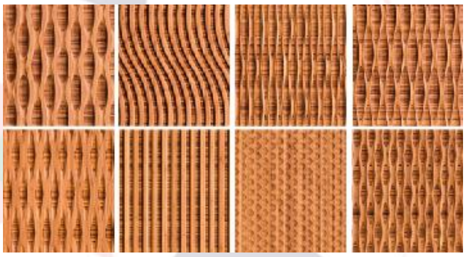
Wall Cladding

BMTPC Recommendation – Govt. of India

Wall cladding	Wall cladding shall be designed to resist wind load. Sheet has to be screwed to the joist / purlin with maximum spacing of 300 mm c/c. All the joints of sheet in longitudinal direction require a minimum lap of 150 mm in order to make them leak proof. Following materials are generally used on wall cladding: • Gypsum board conforming to IS 2095 (Pt. 1): 2011 • Heavy duty cement particle board conforming to IS 14862:2000.
Bracing	Bracing and bridging shall have configuration and steel thickness to provide secondary support for the studs in accordance with the relevant specification for the design of Cold – formed steel structure of members.

✓**Proposed in this project-**

✓**Locally available Compressed Bamboo Panels**



Smart Villages Lab
Culture • Construction • Capacity • Community

Flooring System

Compressed Wood panel or Compressed Bamboo Panel over Metal Decking – Bamboo Panel flooring system available locally fro Bamboo Technology Centre – Chaigaon, Assam

Smart Villages Lab
Culture • Construction • Capacity • Community

Skill development – LGS press & Bamboo press

Smart Villages Lab

Culture • Construction • Capacity • Community

Thank You for your kind attention !

Jayanta Pathak PhD

jayantapathak.ce@ae.ac.in

lecture on Traffic Management
- by Bibhuti B. Bharadwaj

ASSAM ENGINEERING COLLEGE
GAUHATI
SERVICE BEFORE SELF

Design of signalized and coordinated traffic intersections in Guwahati city

Presented by-

Bibhuti B. Bhardwaj

TRAFFIC CONGESTION IS A PROBLEM

- WA
- IN
- IN
- CH
- HU
- WA

POL

GUWAHATI CITY

Traffic Congestion Irks Guwahati City Residents

August 2, 2018 2 Min Read

STAFF REPORTER

GUWAHATI, Aug 1: Guwahati city normal life comes to a standstill every day at GMC Ward No. 13 near Silpukhuri due to traffic congestion that lasts close to an hour during the busy hours of the day. The area generally remains crowded right from 9 am till 10 pm. According to the residents of the locality, during office hours, people remain stuck in the traffic jam and have to spend hours to cover this mere 1.5-km stretch. The same happens between 6 pm and 8 pm.

The 1.5-km stretch of Maniram Dewan Road from Gauhati Club to the Nabagraha point that is within Silpukhuri has converted into a bottle-neck for vehicles coming from both Ulubari and Ambari via Gauhati Club and from RG Baruah Road and Noonmati via Chandmari.

Solutions to traffic congestion problem:

3. Grade separated intersection.

Advantages and Disadvantages:

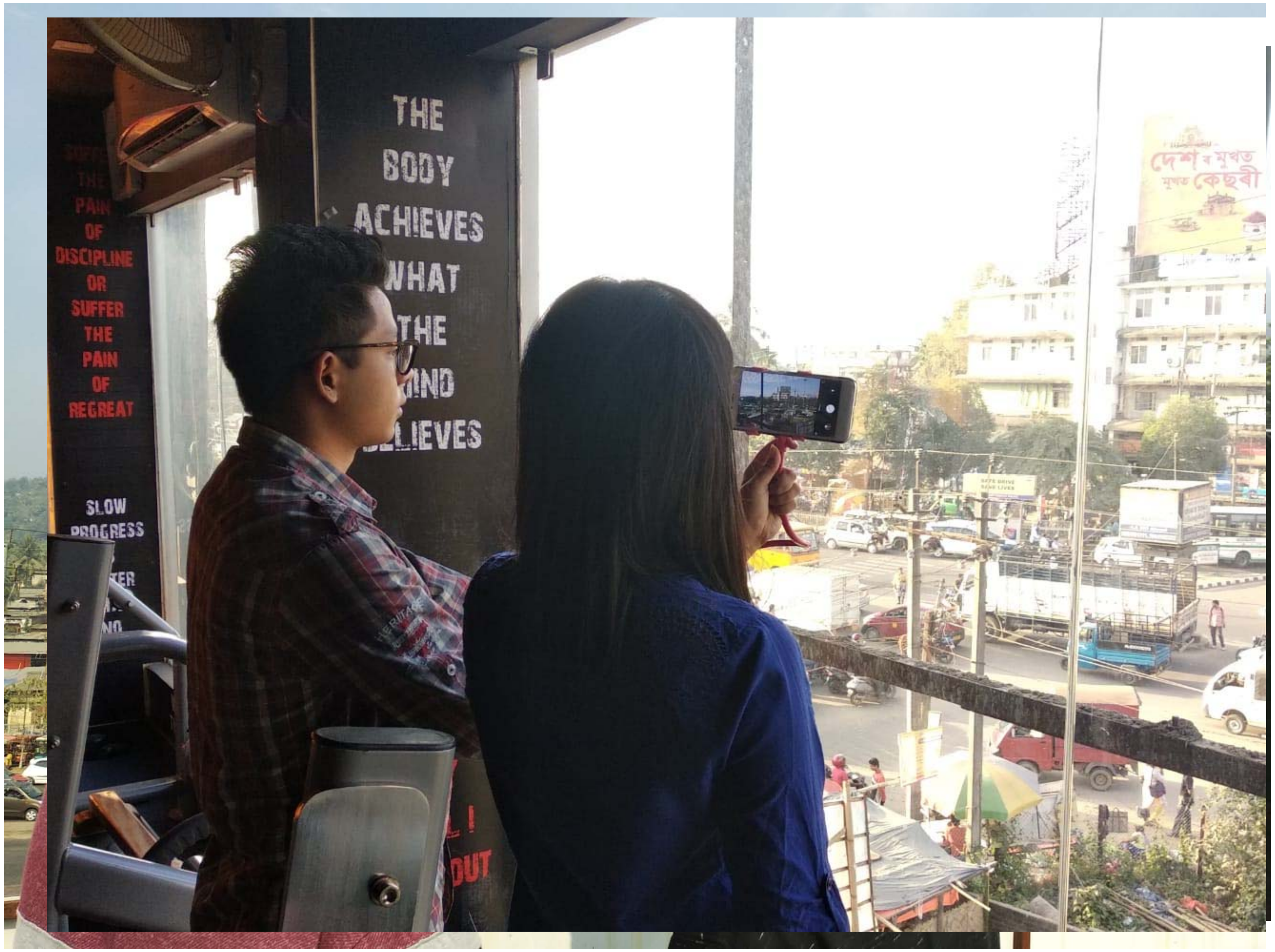
Rotaries	Grade separators	Traffic Signals
➢ Good Aesthetics ➢ Can safely dissipate small traffic volume	➢ Most favorable for congested roads	➢ Low cost ➢ Eliminating conflict points ➢ Least space ➢ Low maintenance
➢ High cost ➢ Conflict Points ➢ Accident prone ➢ Slows down traffic	➢ Highest cost ➢ Time consumption ➢ Parameters are bigger	

SITE SELECTION

- Economic and Strategic importance of NH 37
- Frequent Congestion Problem

Collection of Data

Basistha Chariali intersection



Data Interpretation Process

Data Collection → Conversion of collected Data into → Tabulation of Data

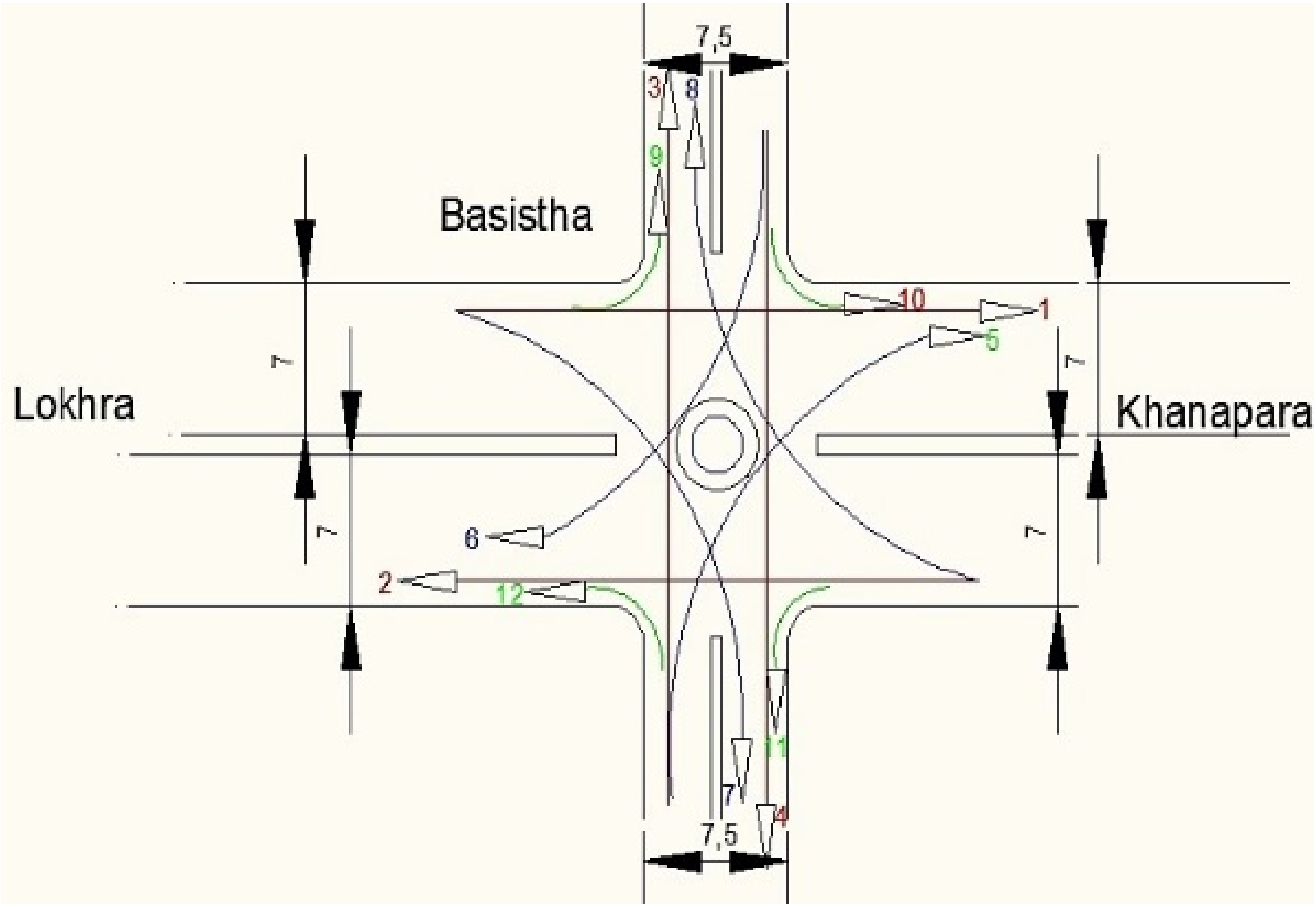
Table C1: Vehicle count at Basistha Chariali intersection for Direction-1

Vehicle Type	Time	10.10.49	10.20.14	10.33.57	10.43.18	10.57.16	11.04.05	11.08.15	11.14.36	11.22.20	11.30.46	11.37.34
	PCU Factor	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle10	Cycle11
1	0.5	32	30	28	33	31	37	35	29	31	29	24
2	1	74	78	71	67	74	65	73	71	76	67	72
3	1.2	2	6	7	4	3	4	0	1	3	0	2
4	1.4	11	38	17	18	19	17	10	18	19	19	20
5	2.2	6	35	22	21	20	19	16	9	11	13	17
6	4	2	1	0	1	0	0	0	1	0	2	0
7	2.2	7	17	13	15	16	20	15	13	12	11	9
8	4	1	0	0	1	0	0	0	0	0	0	0
9	0.4	0	0	0	0	0	0	0	0	0	0	0
10	1.5	0	0	0	1	0	0	0	0	0	0	0
11	1.5	0	0	0	0	0	0	0	0	0	0	0
12	2	0	0	0	0	0	0	0	0	0	0	0

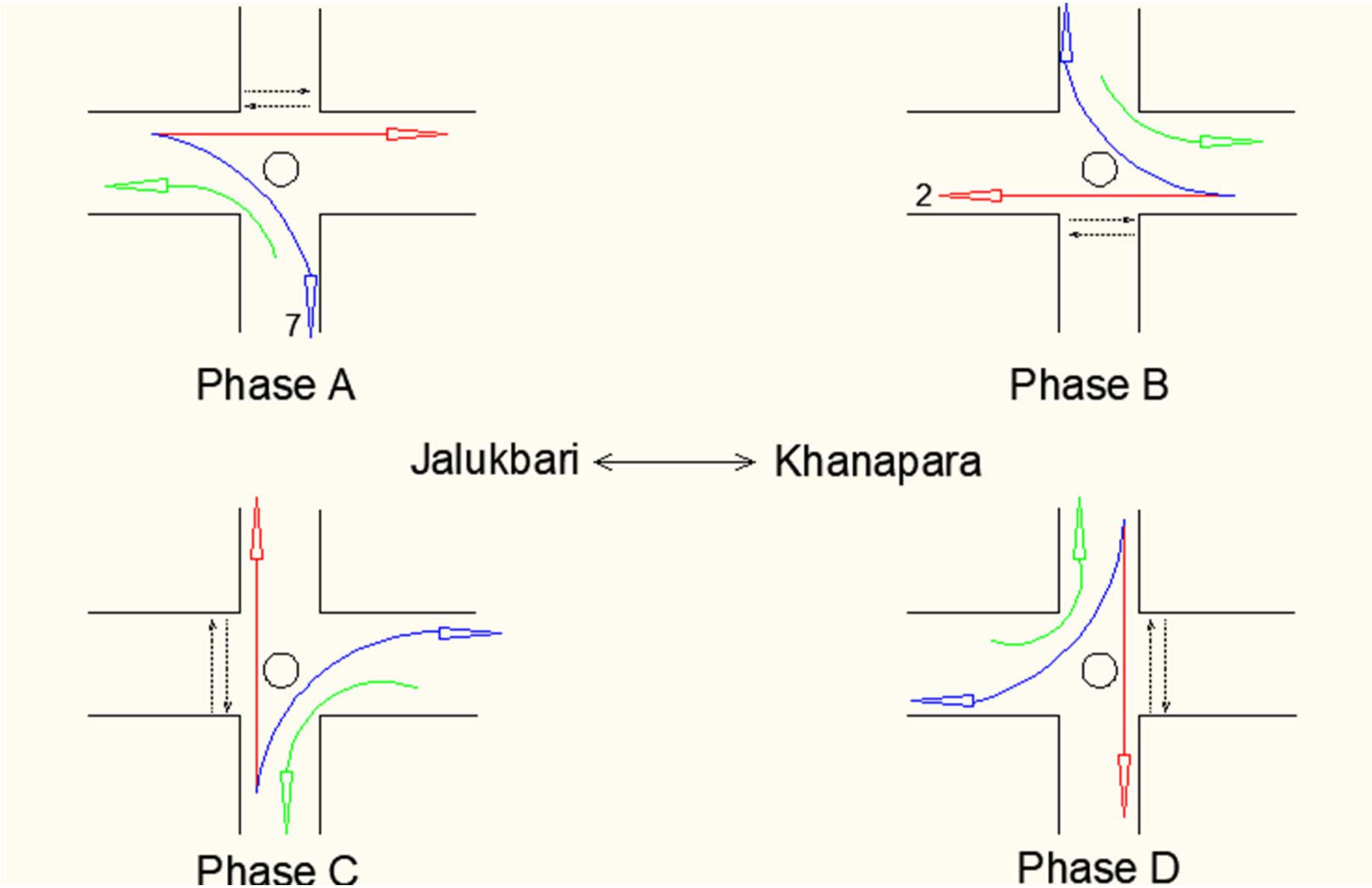
As per IRC: 106-1990

Sl No.	Vehicle Type	PCU Factor
1	Motor Cycle/Scooter	0.5
2	Passenger Car	1
3	Auto Rickshaw	1.2
4	Light Commercial Vehicle	1.4
5	Truck (up to dual rear axle)	2.2
6	Truck (multi rear axle)	4
7	Bus	2.2
8	Agricultural Tractor -Trailer	4
9	Bicycle	0.4
10	Cycle Rickshaw	1.5
11	Horse drawn vehicle	1.5
12	Hand cart	2

Vehicular directions



Designed Phases



Terminologies

Phase

A phase is the green interval plus the change and clearance intervals that follow it..

Cycle

A signal cycle is one complete rotation through all of the indications provided.

Cycle length

Cycle length is the time in seconds that it a signal takes to complete one full cycle of indications.
Interval

It indicates the change from one stage to another.

Green interval

It is the green indication for a particular movement or set of movements

Red interval

It is the red indication for a particular movement or set of movements denying the grant of access.

Amber interval

It is the time interval between Green and Red interval. The amber (yellow) light warns that the signal is about to change to red.

Loss time

It indicates the time during which the intersection is not effectively utilized for any movement.

Methods of design of Traffic Signals: Webster Method

$$C = \frac{1.5L+5}{1-\sum_{i=1}^{P}(V/S)_i}$$

Where,

C: Optimal cycle length, in seconds

L: Lost time during a cycle. Sum of the start-up lost time and the clearance lost times.

p: total number of phases in the cycle

V: volume of a particular movement

S: saturation flow for movement, can be taken as 1400 PCU/lane for urban roads

Further L can be calculated as:

$$L = \sum_{i=1}^{p}(\alpha + \beta + \mu)$$

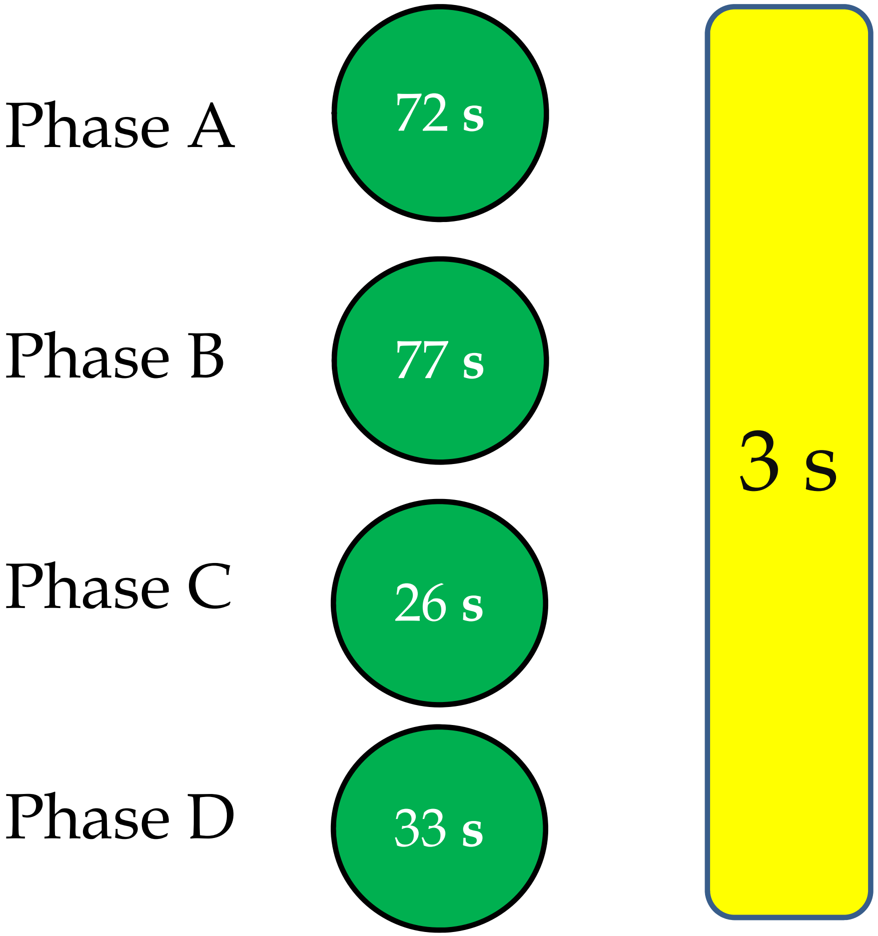
α: startup time loss
β: movement time loss or clearance lost time
μ: all red time loss
P: No. of phases

Phase	Directions	V	S	V/S
A	1	1404	2800	0.501
	7	228.2	1400	0.077
	12	373.15	2800	0.133
B	2	1492.6	2800	0.533
	8	20.6	2800	0.001
	10	280.8	2800	0.101
C	3	251	1400	0.179
	5	173.9	1400	0.124
	11	298.52	2800	0.107
D	4	245.5	2800	0.088
	6	567.7	2800	0.203
	9	631.8	2800	0.226

Phase	Cycle length-(sec)	Allocation (sec)	Green(sec)	Amber(sec)
A	208	208×.501/1.439 = 72.42	72	3
B	208	208×.553/1.439 = 77.04	77	3
C	208	208×.179/1.439 = 25.87	26	3
D	208	208×.226/1.439 = 32.67	33	3

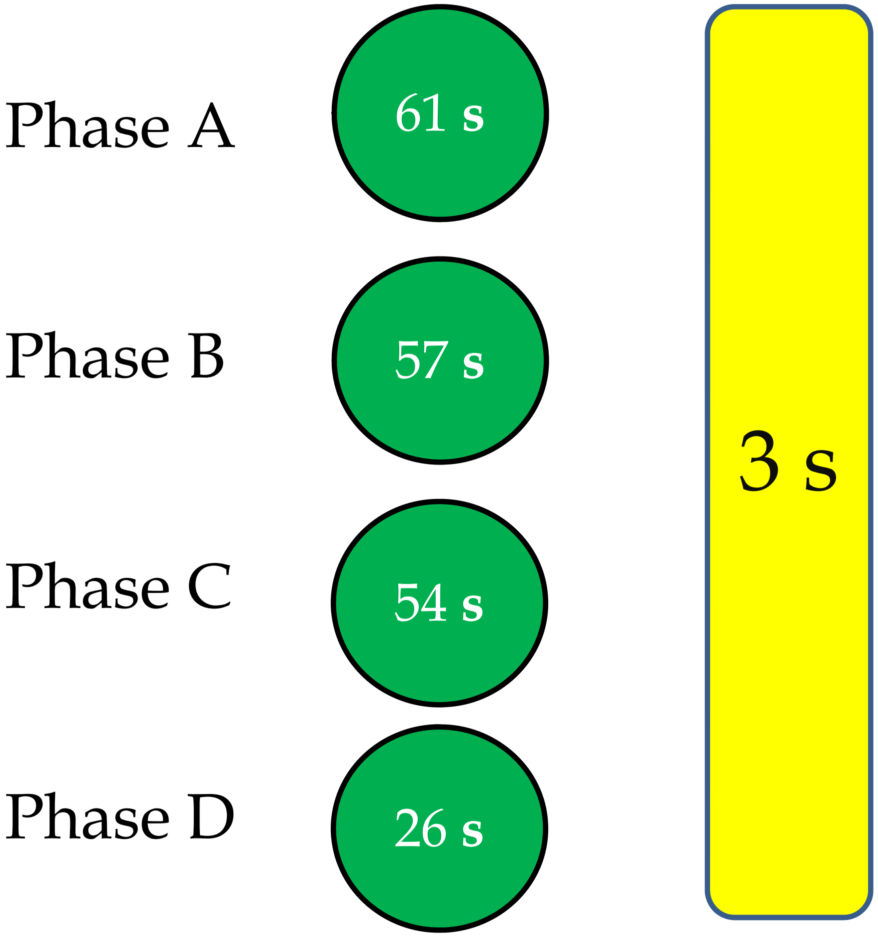
Design of Signals

Basistha Chariali Intersection



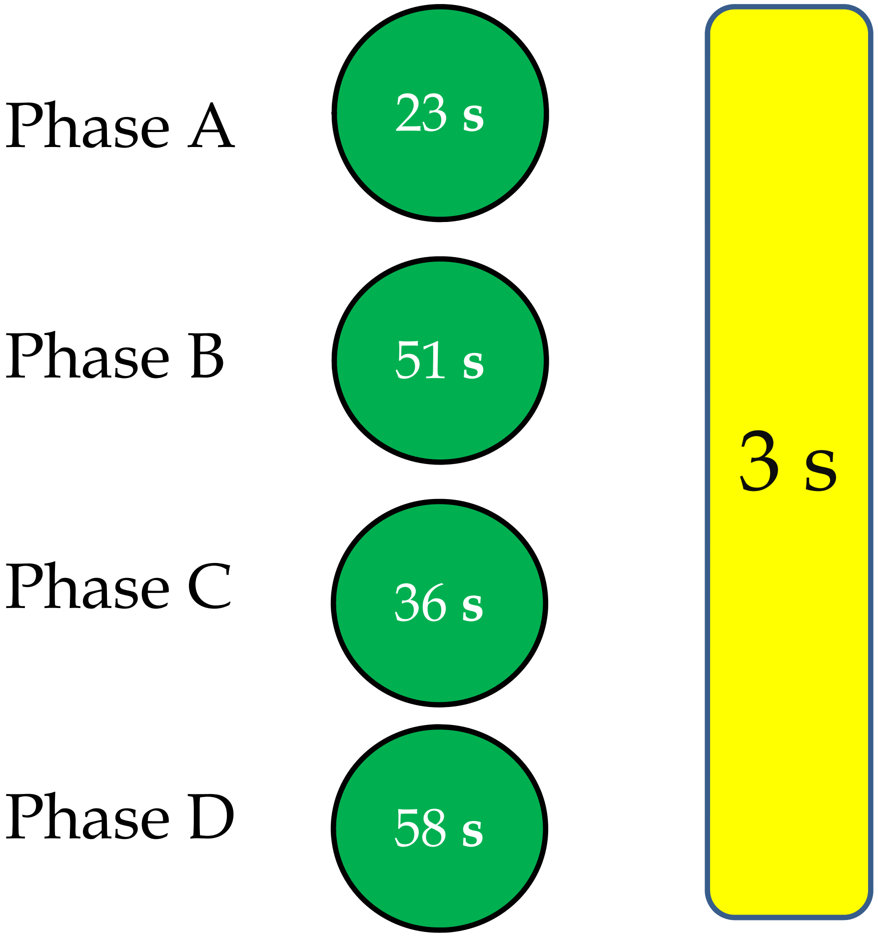
Design of Signals

Lokhra Chariali Intersection

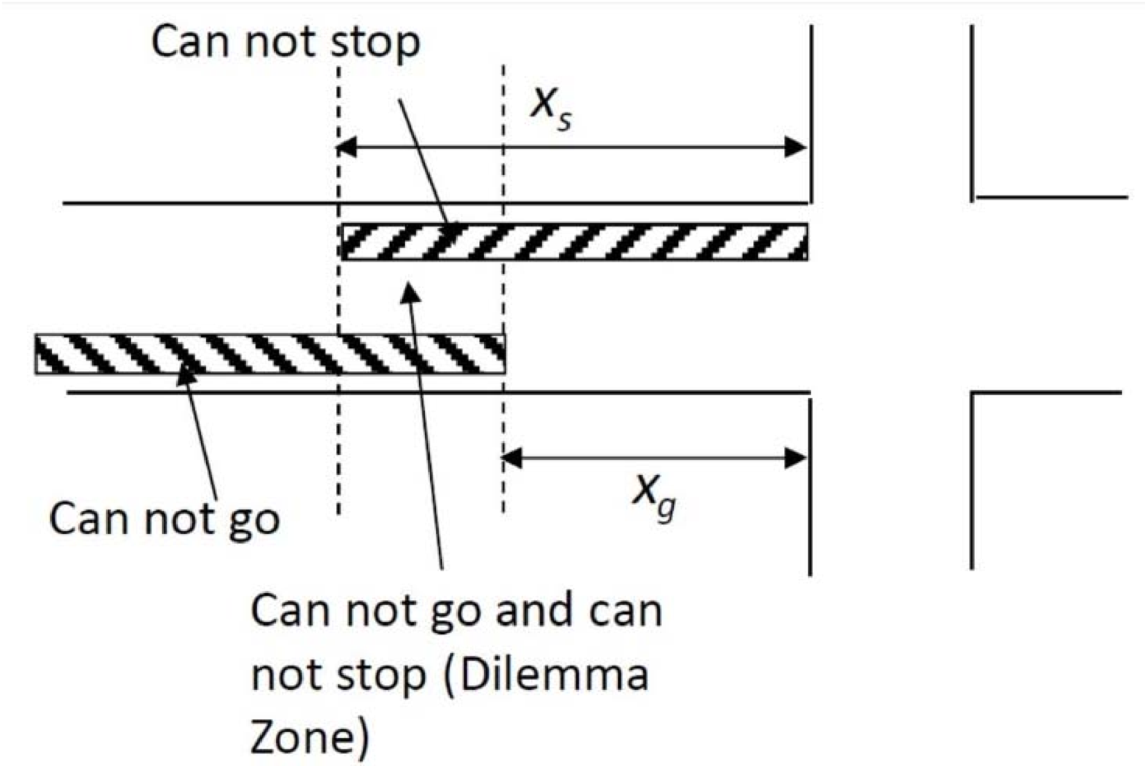


Design of Signals

Garchuk Chariali Intersection



Dilemma Zone

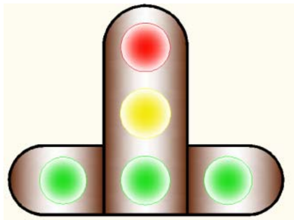


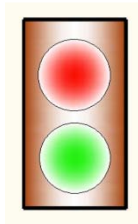
COST SAVING

Present cost

1 Head constable
2 constables
1 home-guard
1 ASI/ 3 intersections

In 5 years → **Rs. 1,28,58,000/-**





Signal cost :

- Signal
- sub-signal
- Vertical posts
- Installation cost
- Power consumption
- Employment cost

In 5 years → **Rs. 20,52,524/-**

Total saving in 5 years = Rs. 1,08,05,476 = 84.04 %

QUESTIONNARE

(Please fill the Answers to the Questions)

1. Intersection
   a. Basistha b.Lokhra c. Garchuk
2. Age of Traffic Police
   a. <25 years
   b. 25 – 35 years
   c. 35-50 years
   d. >50 years
3. Service period
   a. <5 years
   b. 5-10 years
   c. 10-20 years
   d. >20 years
4. Shift of work
   5 - 7 Hours a day, 6 Days a week
5. Are you satisfied with your current salary? (Yes/No)
6. Current gross salary
   a. <25k/month
   b. 25-30k/month
   c. 30-40k/month
   d. >40k/month
7. Rank and designation
   a. ASI
   b. Head Constable
   c. Constable
   d. Home Guard
8. How many traffic inspectors are appointed in that intersection? 4
9. Are the members of traffic inspectors sufficient? No 7 or more
10. If not how many should be there at a time?
11. Shift time? 4 hrs
12. Any other facilities? (Yes/No)
13. Are there any proper instructions on direction and time allowance? (Yes/No)
14. Any information on the other two intersections?

SALARY ANALYSIS

Table : Details of the employment cost to the government per intersection

Sl No.	Designation of the person employed	No. of persons employed per intersection	Monthly Salary (Rs.)	Total Monthly Cost to the Government (Rs.)
1	ASI	0.33	43000	14,300
2	Head Constable	1	40000	40,000
3	Constable	4	30000	1,20,000
4	Home Guard	4	10000	40,000
TOTAL COST TO THE GOVERNMENT				2,14,300

Signal Coordination

▪Total waiting time = 2 min 57 sec

Time Saving

WITHOUT TRAFFIC SIGNALS:

Trip No.	Khanapara to Jalukbari (in minutes)	Jalukbari to Khanapara (in minutes)
1	27.3	29.3
2	34.5	30.5
3	40.2	38.6
4	42.6	39.5
5	40.9	41.3
6	38.6	42.6
7	35.4	37.3
8	36.5	38.5
9	32.6	35.2
10	37.6	35.6
Average Time	**36.62**	**36.84**

WITH TRAFFIC SIGNALS:

direction	Optimistic time	Pessimistic time	Average
Khanapara to Jalukbari	18.67 minutes	25.6 minutes	21.14 minutes
Jalukbari to Khanapara	21.62 minutes	29.03 minutes	25.32 minutes

Adding 20% for loss due to interaction with other vehicles.

i.e. time taken from Khanapara to Jalukbari= 26.57 minutes
Similarly, time taken from Jalubari to Khanapara = 30.4 minutes

Conclusion

Summary of the traffic signal details

Phases	Basistha		Lokhra		Garchuk	
	Green	Amber	Green	Amber	Green	Amber
Phase A	72	3	61	3	23	3
Phase B	77	3	57	3	51	3
Phase C	26	3	54	3	36	3
Phase D	33	3	26	3	58	3
Total time	220s		210s		180s	
Distance	4.83 km between Basistha and Lokhra			4.13 km between Lokhra and Garchuk		

The users can save 27.4% of their time while commuting from Khanapara to Jalukbari

The users can save 17.4% of their time while commuting from Jalubari to Khanapara

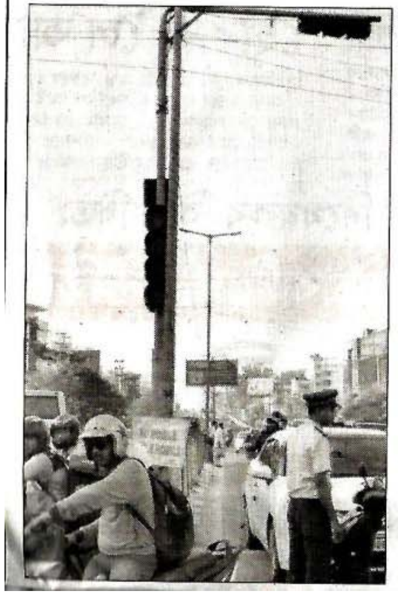
The government can save 84.04% of the taxpayers' money

Ranjeet Singh, 38, a traffic police in Odisha says that using these skills, one can reduce the violations of traffic in their concerned area

Hum aapke jaisa fit thodi
naa hain Shukla jee

যান-জঁটত অতিষ্ঠ চালক-যাত্ৰী-পথচাৰী, নিৰ্বিকাৰ মহানগৰ আৰক্ষী

গুৱাহাটীত দুবছৰে বিকল ট্ৰেফিক ছিগনেল লাইট



২১ টা ছিগনেলৰ আটাইকেইটাই অকামিলা

প্ৰতিদিন মহানগৰ সেৱা, গুৱাহাটী, ২৬ নৱেম্বৰ ঃ বিভাগীয় দায়িত্বহীনতাৰ বাবেই সম্প্ৰতি বিকল হৈ আছে মহানগৰীৰ আটাইকেইটা ট্ৰেফিক ছিগনেল লাইট। গুৱাহাটীৰ মুঠ ২১টা স্থানৰ ছিগনেল লাইট বিকল হৈ থকাত মহানগৰীৰ ই তিটো পথত ভয়ংকৰ যান-জঁটৰ সৃষ্টি হয়। যান-জঁটত গুৱাহাটীবাসীয়ে প্ৰতিদিনে ত্ৰাহি মধুসূদন সুঁৱৰিছে যদিও বিষয়টোত নিৰ্বিকাৰ হৈ আছে মহানগৰ আৰক্ষী। মুঠ ২১টা স্থানৰ অধিকাংশ ট্ৰেফিক পইণ্টৰ ছিগনেল লাইট প্ৰায় দুবছৰ বিকল হৈ থকাৰ বিপৰীতে সক্ৰিয় হৈ থকাকেইটাও সম্প্ৰতি বিকল হৈ পৰিছে। উল্লেখযোগ্য যে প্ৰতিদিনে ছয়মাইলৰ পৰা দিছপুৰ ছুপাৰ মাৰ্কেটলৈ, গণেশগুৰি উৰণীয়া সেতুৰ তলত, জি এছ ৰোডৰ শ্ৰীনগৰ পইণ্ট, এ বি চি পইণ্ট আৰু চানমাৰি অঞ্চলত ভয়াৱহ যান-জঁটৰ সৃষ্টি হৈ আহিছে। মহানগৰীৰ জয়ানগৰ, ডাউন টাউন, দিছপুৰ ছুপাৰ মাৰ্কেট, গণেশগুৰি, জু-ৰোড তিনিআলি, কমাৰ্চ পইণ্ট; চানমাৰি, শিলপুখুৰী, গুৱাহাটী ক্লাব, উলুবাৰী, ভঙাগড়, এ বি চি পইণ্ট, শ্ৰীনগৰ পইণ্ট, নুনমাটি, কাৰ্বন-গে'ট, কাছাৰী, পাণবজাৰ, মালিগাঁও, আদাবাৰী, কামাখ্যাগে'ট, জালুকবাৰীকে ধৰি মুঠ ২১টা পইণ্টত ট্ৰেফিক ছিগনেল লাইট আছে। কিন্তু এই ২১টা পইণ্টৰ কাৰ্বন গে'ট, ডাউন টাউন আৰু কমাৰ্চ পইণ্টৰ ছিগনেল লাইটকেইটা মাজে-সময়ে জ্বলে যদিও বেছিভাগ সময়ে নুমাই থাকে। তদুপৰি আটাইকেইটা পইণ্টত যান-বাহন নিয়ন্ত্ৰণৰ বাবে আৰক্ষীও উপস্থিত নথকাত এচাম চালকে জধে-মধে গাড়ী চলাই যান-জঁটৰ সৃষ্টি কৰে। বিশেষকৈ ভঙাগড়, উলুবাৰী আৰু গণেশগুৰি উৰণীয়া সেতুৰ তলৰ ছিগনেল লাইট বিগত প্ৰায় দুবছৰে বিকল হৈ থকাত চাৰিও দিশৰ পৰা চলাচল কৰা যান-বাহন নিয়ন্ত্ৰণ কৰা আৰক্ষীৰ বাবে অসম্ভৱ হৈ পৰিছে। কিন্তু পথচাৰী চালক যাত্ৰী আৰু যান-বাহন আৰক্ষীৰ সমস্যালৈ তিলমানো গুৰুত্ব নাই শীতাতপ নিয়ন্ত্ৰিত কোঠাৰ পৰা দায়িত্ব সমাপন কৰা আৰক্ষীৰ উচ্চস্তৰীয় বিষয়াসকলৰ। প্ৰাপ্ত তথ্যমতে আৰক্ষী বিভাগে এই ছিগনেল লাইট মেৰামতি তথা পৰিচালনাৰ বাবে নিৰ্দিষ্ট এজেন্সিক দায়িত্ব দিয়ে। কিন্তু এজেন্সিক দায়িত্ব দিয়াৰ পাচতো মহানগৰীৰ সকলো ছিগনেল লাইট বিকল হৈ থকা বিষয়টোৱে প্ৰতিক্ৰিয়াৰ সৃষ্টি কৰিছে। আনহাতে এই সন্দৰ্ভত আৰক্ষীৰ এটা সূত্ৰই জনোৱামতে ছিগনেল পইণ্টত বিজ্ঞাপন লগোৱা নিৰ্দিষ্ট এডভাৰ্টাইজিং এজেন্সিক উক্ত ছিগনেল লাইটৰ মেৰামতি আৰু পৰিচালনাৰ দায়িত্ব দিয়া হয়। নিৰ্দিষ্ট এজেন্সিয়ে পৰিচালনা নকৰাৰ ফলতে পইণ্টসমূহ বিকল হৈ থকা বুলি জানিব পৰা গৈছে। পৰৱৰ্তী সময়ত এই সন্দৰ্ভত আৰক্ষীৰ বৰমূৰীয়াসকলে কি ব্যৱস্থা গ্ৰহণ কৰে সেয়া লক্ষণীয় হ'ব।

Students who underwent the project

Hena Chandni Devi
Bidyut Bikash Boruah
Rajpritom Bora
Bhaskar Jyoti Hazarika
Sumit Agarwalla
Barelong Terang

Thank You

List of participants

18/01/2019

classmate
Date
Page

	Name	E Mail
1	KHAGEN NATH JE	Khagennalbari@gmail.com.
2	TAFSAR ALI, A.E.	me_afsarali@rediffmail.com
3	PRANAB SARKAR J.E(C)	pranab1986@rediffmail.com.
4	ANILKR SAIKIA JE(C)	anil661947@yahoo.in anil19661947@gmail.com
5	Ila Datta Baruah J.E.(A)	iladattabaruah@gmail.com
6	SANJIB BARUWATI(A.E)	Sanjebbaruwati200@gmail.com
7	Suman Dey.	Suman87603@gmail.com
8	ANUP KUMAR DAS (DD)	anup_kd@rediffmail.co
9	Azad Hussain Laskar	azadtep@gmail.com
10	Debojit Das (AE)	~~deb~~ er.debojitdas@gmail.com
11	Debaraj Kalita DD.	debarajkalita@gmail.c
12	KABITA BALA BANIA JE(A)	kabilabania009@gmail.com.
13	Jebina Yasmin	jebina.gca@gmail.com
14	Praschaya Kaushik.	praschayakaushik12@gmail.com.
15	Mashuk Ahmed Laskar	laskarmazhuk@gmail.c
16	Ratan Ch. Mandal. J.E	ratandp@gmail.com.
17	B.K. Sarmah	bk8arma08@gmail.com
18	Rubi Hazarika	Rubidip2016@gmail.com rubihazarika9864@gmail.com
19		
20		

17/01/2019

Name	Mobile Number	Signature
Debojit Das, AE	99540-82187	
Anil kr Saikia, JE	9435335993	
Mashuk Ahmed Laskar	98640-54468	
Khagen Nath JE, T&CP. Nalb.	9101065559	
Anup Kumar Das, Dy Director	8133835354	
Debaraj Kalita. Dy. Director, T&CP.	7002802916	
Azad Hussain Laskar, AE, T&C.P	9435345942	
Ratan Ch. Mandal J.E, T&CP.	9706062539.	
Suman Dey A.E. T&CP.	94350-87603	
Rubi Hazarika J.E. T&CP, Dibrugarh	98641-30870	
Ila Datta Baruah J.E. T&CP Ghy	98641-30651	
Kabita Bala Baruia. JE, T&CP Ghy.	99570-91638	
Pranab Sarkar, J.E, T&CP, Naj.	98642-96473	17/1/19.
Afsar Ali, A.E, T&CP, Dhubri	7002868554	17-01-19
SANJIB BARUATI, A.E., T&C.P. Jorhat	9706065812	17-01-2019
HEMANTA DOLOI, MELBOURNE	8812938346	
JAYSHREE HAZARIKA, AEC	99545-77443	Jayshree Hazarika
JAYANTA PATHAK, AEC	995407777 2	


CAPACITY BUILDING ON CONSTRUCTION MANAGEMENT
[FOR DEPARTMENT OF TOWN & COUNTRY PLANNING, ASSAM]
ORGANISED BY
UNIVERSITY OF MELBOURNE, AUSTRALIA
&
ASSAM ENGINEERING COLLEGE, INDIA
Multi-Skilling and Sustainability Initiative of AEC, Guwahati
Date: 17-24 January, 2019
MELBOURNE
Smart Village Lab