A Practical Approach to Construction Industry Using Best Value and Six Sigma Techniques

Presented by

SHARVARI MANGESH RATH

(15CEM11/ANJUMAN-26)

Under the Guidance of

DR. R.B. MAGAR

Anjuman-I-Islam's Kalsekar Technical Campus

M.E. (CE&M)

Civil Engineering Department

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Overview

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Introduction

1. Quality Management Programs

- Cultural Changes required to meet Quality Management:

From	To
Inspection orientation	Defect prevention
Meet the specification	Continuous improvement
Get the product out	Customer's satisfaction
Individual Input	Co-operative efforts
Short term objectives	Long term vision
People as cost burden	Human resource as an asset

2. Best Value System as a Quality Management Technique

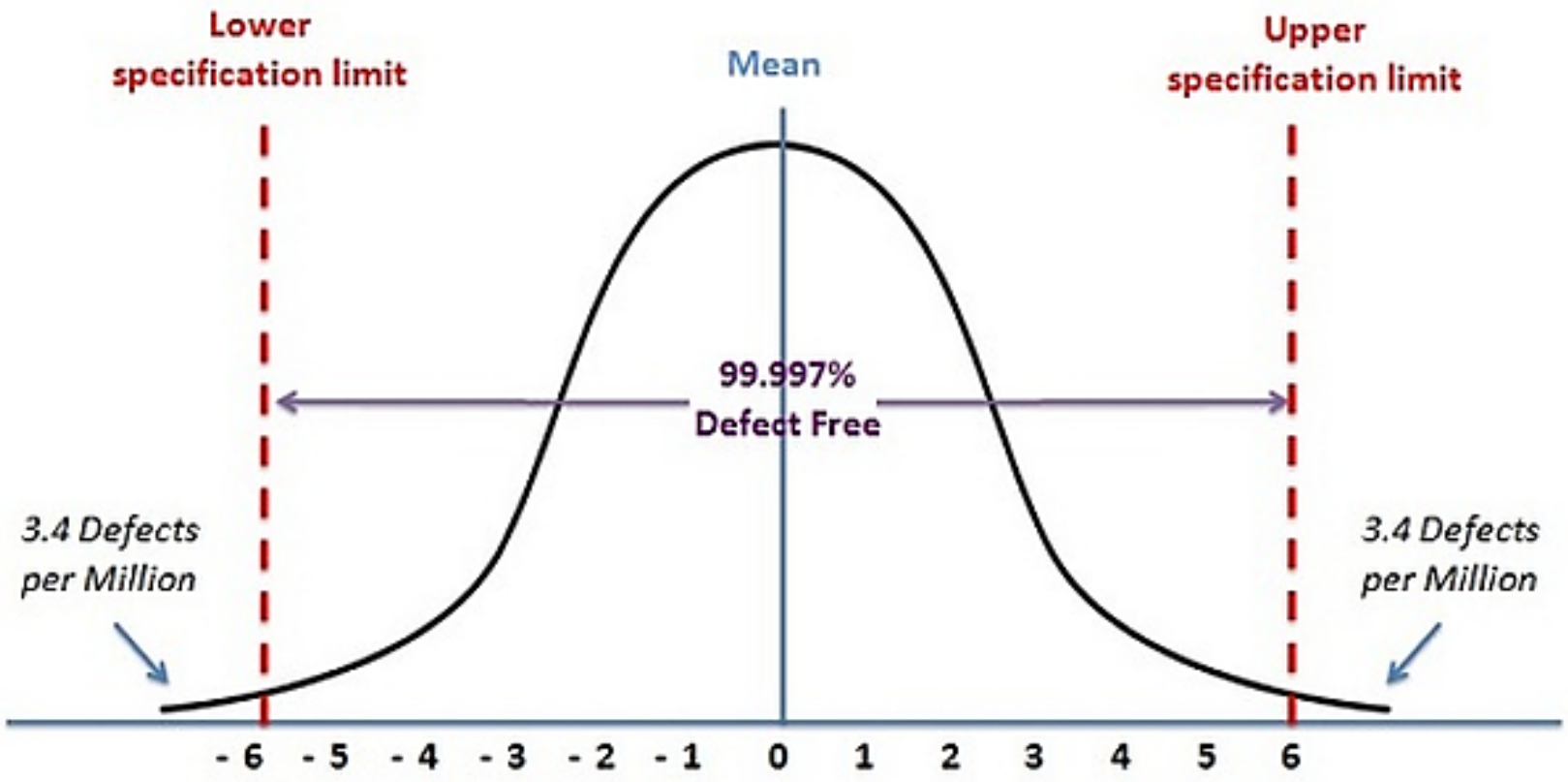
- The best value system was initially developed at the Performance- Based Studies Research Group at Arizona State University in 1994.

- The best value system focuses on improving quality through the elimination of waste by using two primary methods:
  - Reducing client decision making.
  - Minimizing the need for client management and direction.

3. Six Sigma as a Quality Management Technique

- ‘Sigma’ – Useful measure of dispersion.
- Statistical tool – To measure the variation in existing set of data, group of items, process, product or services.
- Measurement Unit – Defects per Million Opportunities (DPMO)
- Focus :
  - Understanding and Managing Customer Requirement.
  - Aligning key Business Process to Achieve Requirement.
  - Utilizing Data Analysis to Minimize Variation.
  - Driving Rapid And Sustainable Improvement.

3. Six Sigma as a Quality Management Technique (Han et al. 2008)



Motivation

- Lack of appropriate application of Quality Management Techniques in Construction Industry.
- Lack in proper documentation of practical approach, validation and reliability of several management techniques.
- Selection of appropriate Contractor/Vendor for a given project.

Aims and objective of study

- Reviewing and identifying the various criteria used for contractor's pre-qualification and bid evaluation.
- Recommendations for enhancing the contractor's selection process.
- Developing a parameter model and assigning weightage to various parameters for effective selection of contractors.
- Providing best value contractor to a project and validate the results obtained using another effective Quality management technique.

Scope of Proposed work

- To fix the initial conditions in accordance to predict final project output.
- Elimination of low bid selection process of various agencies on site.
- Setting various selection parameters for a contractor and deciding the ranking based on the weightage calculated for various parameters.
- Selection of a best value contractor and validating the performance by six sigma technique.
- Assigning the sigma level to the project contractors.
- Predicting the project completion quality based on the best value technique and six sigma technique.

Literature Review

- Quality Management Programs in Construction industry:

Author	Title	Journal	Year	Findings
Murray	A construction contract for the year 2000.	Concr. Int., 15(6), 60–61.	1993	• Construction industry processes reporting major defects. • Over budgeted or Late completion. • Lacks in appropriate usage of Quality Management Program.
Areola	A key sector suffering from funding constraints and irregularities.	Pak. Gulf Economist, 97(15).	1997	
Georgy et al.	Engineering performance in the U.S. industrial construction sector.	Cost Eng., 47(1), 27–36	2005	
Sullivan	The influence of an information environment on a construction organization's culture: A case study.	Adv. Civ. Eng., 2009, 1–10	2011	

- Quality Management Programs Compared with Best Value System:

Author	Title	Journal	Year	Findings
Sullivan	Quality Management Programs in the Construction Industry: Best Value Compared With Other Methodologies.	Journal of Management and Engineering, 27(4), pp. 210-219	2011	• Analysed three popular Quality Management Program, TQM, Lean Production, Six Sigma and contrasted it with Best Value System.

- Application of Best Value Model in Construction Industry :

Author	Title	Journal	Year	Findings
Scott et al.	Best-value procurement methods for highway construction projects.	Rep. No. 561, Project No. 10-61, NCHRP, Transportation Research Board, National Research Council, Washington	2006	• Procurement of public-sector building projects in Korea using Best Value Technique.
Abdelrahman et al.	Best-value model based on project specific characteristics.	Journal of Construction Engineering and Management, 134(3), 179–188.	2008	• Presented a model for procurement using Best Value Technique.
Park et al.	Practical Tool for Assessing Best value at the procurement Stage of Public Building in Korea.	Journal of Management in Engineering, 31(5)	2015	

- Contractor Selection Process:

Author	Title	Journal	Year	Findings
Holt et al.	A review of contractor selection practices in the U.K. construction industry.	Build. Environ., 30(5) , 533–561.	1995	• Selection of Contractors is on basis of lowest bid – price. • Selection of lowest bidder is major reason for project delivery problems. • Selection should be based on set of multiple decision criteria.
Skitmore et al.	Criteria for contractor selection.	Construction management Economics, 15, pp. 19-38.	1997	
Fong et al.	Final contractor selection using analytical hierarchy process.	Constr. Manage. Econom., 18, 547–557.	2000	
Singh et al.	Contractor Selection Criteria: Investigation of Opinions of Singapore Construction Practitioners.	Journal of Construction Engineering and Management, 132(9), pp. 998-1008.	2006	

- Application of Six Sigma in Construction Industry:

Author	Title	Journal	Year	Findings
Pheng et al.	Implementing and Applying Six Sigma in construction.	Journal of Construction Engineering and Management, 130(4), pp. 482-489	2004	• Applied Six Sigma to improve the quality of internal finishes and raise the sigma Level.
Pataskar et al.	Applying Six Sigma Principles in Construction Industry for Quality Improvement.	ICAET	2014	
Han et al.	Six sigma based approach to improve performance in construction operations.	J. Manage. Eng., 24(1), 21–31.	2008	• Studied Performance changes based on six sigma principles.

Research Gap

- The construction industry mainly focuses on low-price based environment.
- Though Best Value system was introduced as value-based technique but its major application was observed in procurement.
- The current trend observed in the construction industry is to focus on the selection of the vendor or contractor on the basis of lowest bid price.
- Less research work carried out for validation of the quality management techniques applied in construction industry.
- Even Six sigma analysis technique is rarely used in construction industry to rate the contractors for the construction work carried out.

Best Value Technique

1. **Phases of Best Value:**
   - Preparation phase
   - The selection phase
   - The pre-award phase
   - Execution
2. **Measure performance by Filtration process**
3. **Transfer of Project Responsibility**

Six Sigma Technique

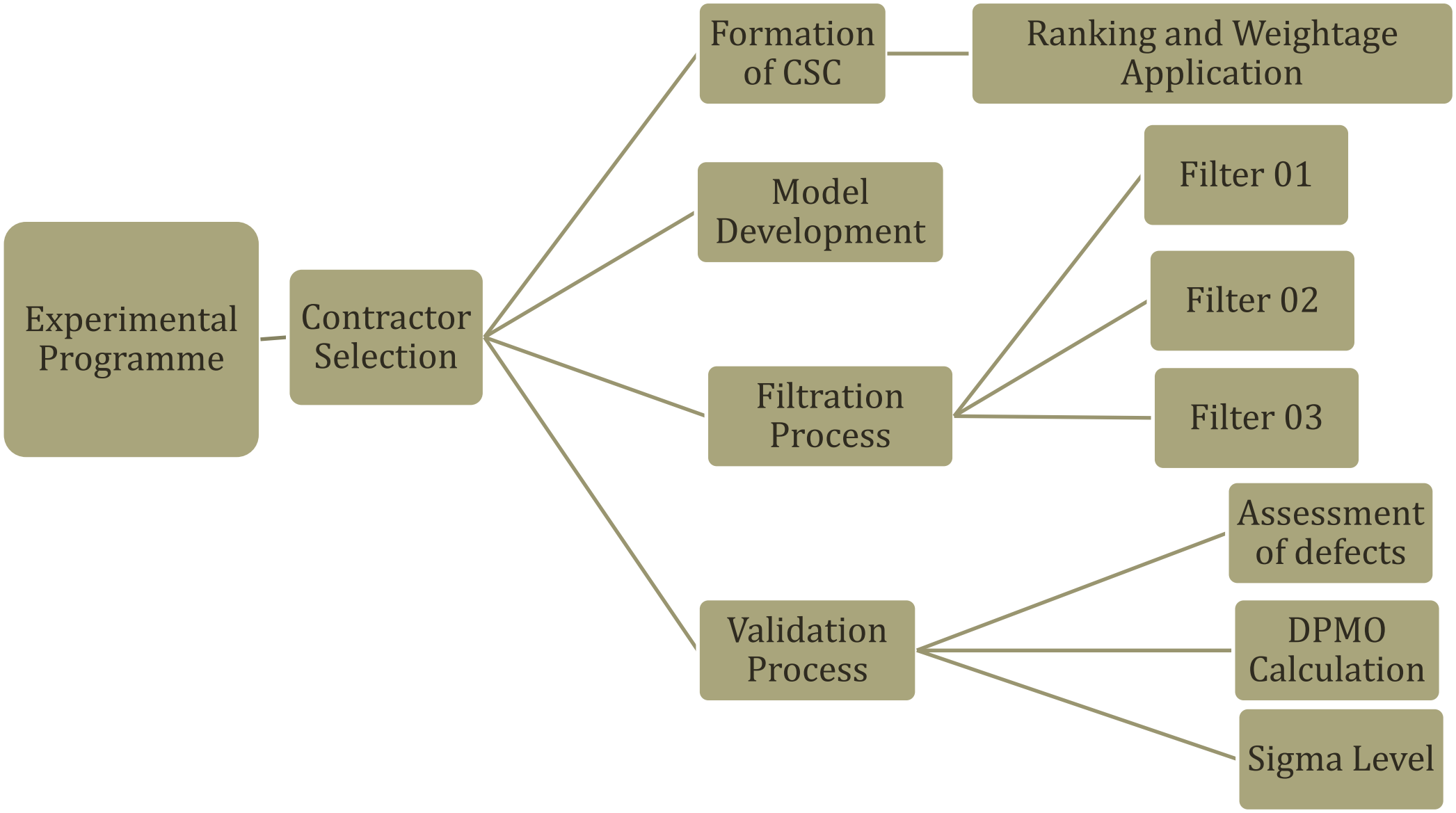
1. Define Opportunities
2. Measure Performance
3. Analyse Opportunities
4. Improve Performance
5. Control Performance

Research Methodology

Experimental Programme

- To identify the project site for application of the problem statement.
- Develop the various parameters for selection of the contractor.
- Grouping of parameters and developing the relation amongst them.
- Model development for selecting the highest suitable contractor.
- Application of Best Value technique for filtration of contractor.
- Selection of Contractor.
- Application of Six sigma technique on Contractor.

Experimental Programme Flow chart



1. Development of Contractor selection criteria (CSC)

- The system eliminates owner inefficient and bias decision making by replacing the selection process.
- The process aligns the owner with party that can best fulfill the owner's need.
- Process:
  - Based on literature survey, project experiences, interviewing professionals - 85 CSC developed.
  - Shortlisting of CSC – 41 CSC shortlisted.
  - Grouping of CSC in 05 major attributes.

Major Contractor selection criterion group:

Group	Criteria	Measurement Capability
I	Contracting company's attribute	These Criteria Measure The Reputation Of The Company, Its Post-Business Attitude, Quality Achievements, Health And Safety Records
II	Past performance information	These criteria assess the level of expertise offered by the contractor.
III	Financial capability of the contracting firm	These decision criteria measure the financial soundness of the contracting company and its ability to meet current liabilities, long-term financial obligations, and to carry current commitments along with the project under consideration.
IV	Performance potential of the contractor	This criteria group evaluates the availability of the resources and experience level of the contracting firm in similar types of project.
V	Project specific criteria	This group assesses the level of technical and management skills of the contracting company in light to the project under consideration.

Contractor Selection Criteria:

Sr.no	Major CSC	Particulars
1	Contracting Companies Attributes	Age of Company
2		Familiarity with the regulating Authorities
3		Familiarity with local Working Culture
4		Health & Safety Records of the Company
5		Achievement of the Quality Level
6		Past Failures
7	Past Performance of the Contractor	Type & Scale of the project Completed in last 03 yrs
8		Quality of work in past project
9		Percent of previous work completed on schedule
10		Standards of subcontractor work in past projects
11		Attitude towards correcting faulty works
12		Good relationship with past project owners
13		Relationship with sub-contractors
14		Relationship with suppliers
15		Relationship with regulating Authorities

Contractor Selection Criteria:

Sr.no	Major CSC	Particulars
16	Financial Capabilities	Current Commitments
17		Working Capital
18		Current & Fixed Assets
19		Turnover
20		Profit generating Ability of the Company
21		Capital Structure of the Company
22		Finance Arrangement
23	Performance Potential of the Contractor	Qualification & Experience of Technical Staff
24		Qualification & Experience of Management Staff
25		Depth of Experience on similar type of project
26		Manpower Resources
27		Availability of owned construction plant & Equipment
28		Present Workload & Capability to support the current project
29		Quality Control & Assurance Program
30		Specialized knowledge of particular construction method

Contractor Selection Criteria:

Sr.no	Major CSC	Particulars
31	Project Specific Criteria	Construction Method Statement
32		Proposed project time Schedule
33		Qualification & Experience level of project Manager
34		Qualification & Experience of professional technical Staffs
35		Experience level of project team on similar type of project
36		Number of direct workers available for the project
37		Availability of testing equipment as quality assurance
38		Health & Safety setup for the project
39		Checklist available with Contractor
40		Estimation Softwares Available with the firm
41		Licensed Softwares availability

2. Relative Importance Index (RII)

- To find degree of importance of each CSC.
- Weight of every CSC was collected in terms of '1 to 5' (less significant to extremely significant respectively).
- Expression for RII:

$$RII = \frac{\sum^{n} W}{A \times N} \quad \text{.... Eq (1)}$$

Where,

W = Weight factor by respondent

A = Highest weight given to the criteria

N = Total no. of responses

(Muhwezi et al. 2014)

3. Weighted Average Method (WAM)

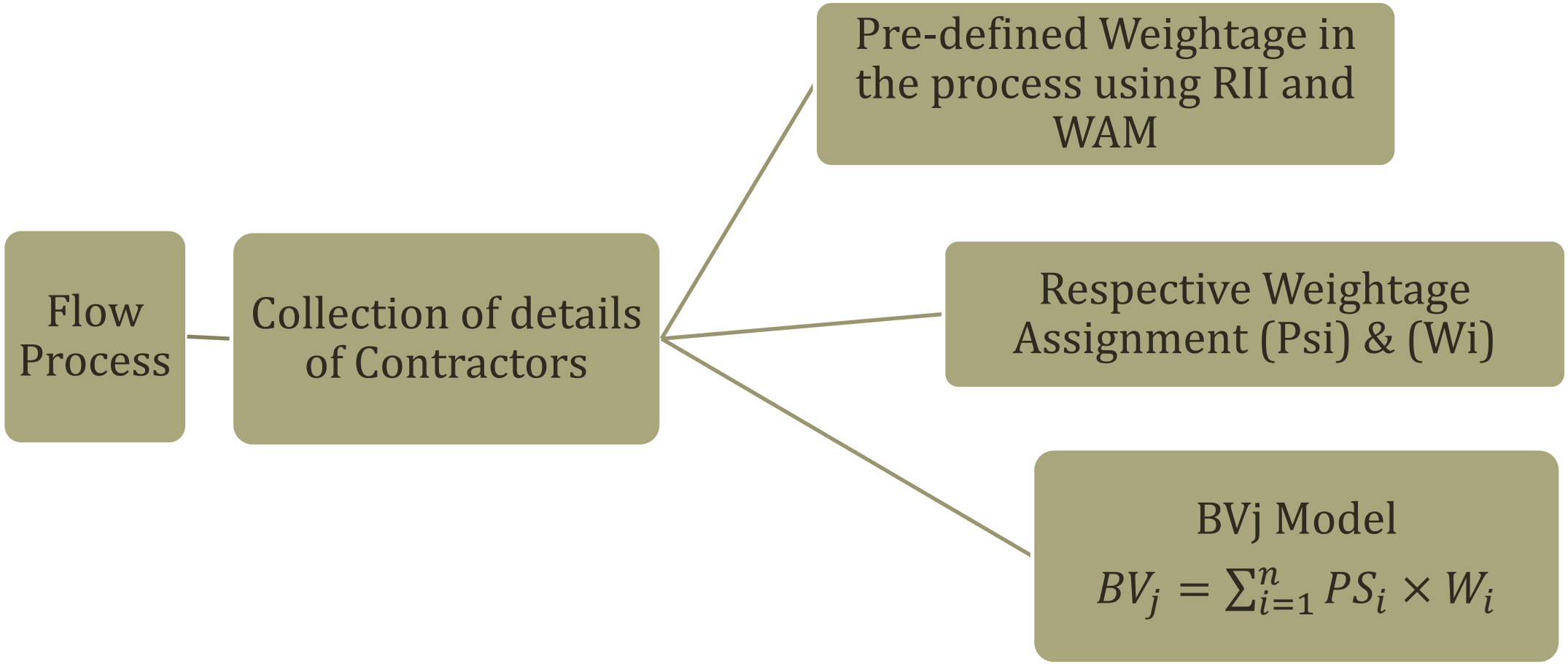
- Weight scale is used to represent 01 to 05 ratings.
- Expression for WSR:

$$\boldsymbol{Weight\ Scale\ (WSR)} = \left(\mathbf{1} - \frac{\boldsymbol{rate}-\mathbf{1}}{\mathbf{5}-\mathbf{1}}\right) \times \mathbf{100} \qquad \text{.... Eq (2)}$$

Where, rate = rating between 01 to 05 obtained from the respondents. (Abdelrahman et al. 2008)

- Relative Weight (Wi) is obtained from the WSR.

4. Best Value Model (Work Flow chart)



5. Contractor Selection (Filtration Process)

Filter 01

- BVj attainment on 05 Major attributes
- Value based environment

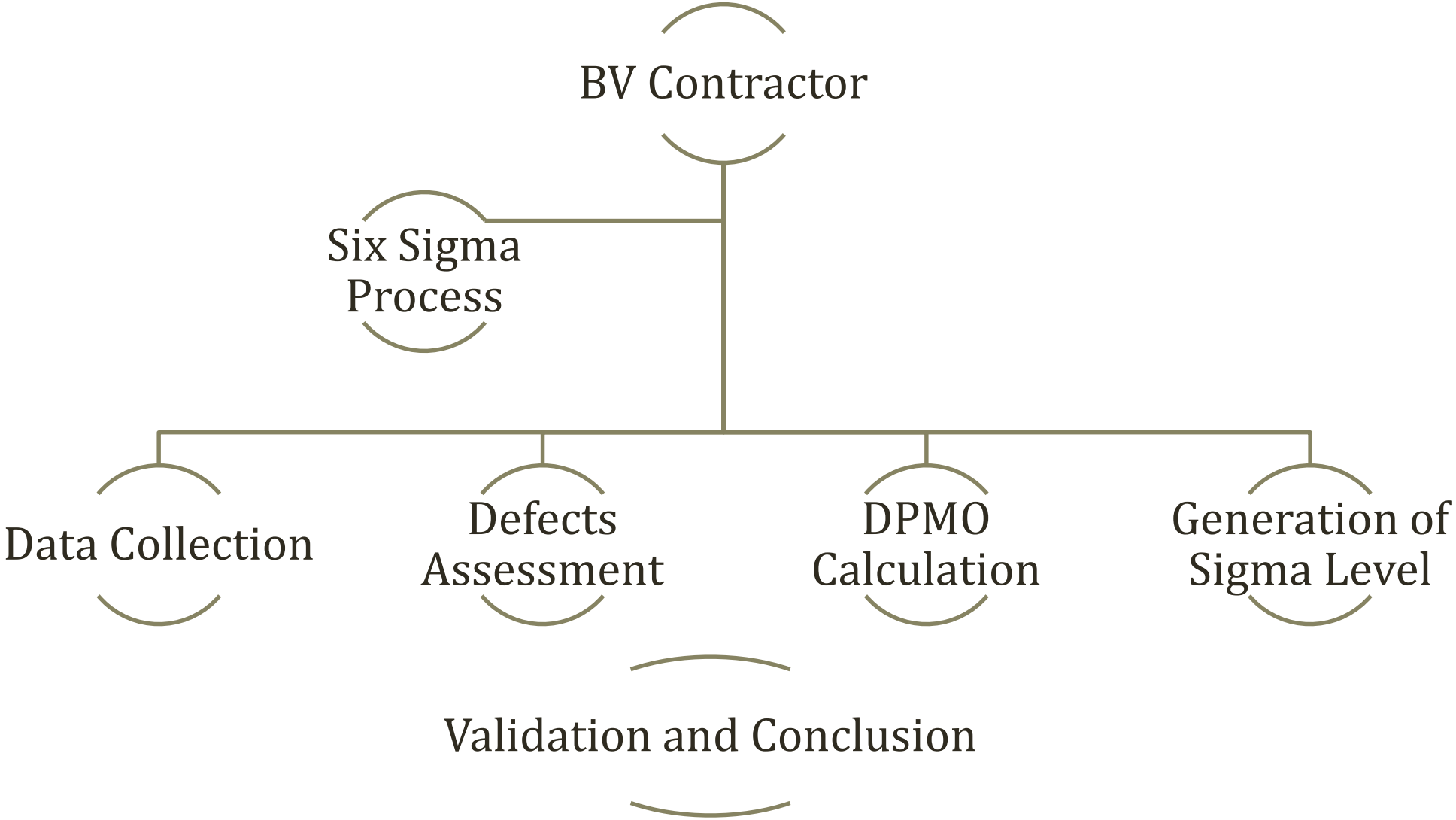
Filter 02

Verification Stage

Filter 03

- BVj attainment on low price bid
- Price based environment

5. Six Sigma Techniques (Validation Process)



Results and Discussion

1. Findings from RII and WAM Model

- RII and WAM used in weight assignment
- Correlation: 0.93 (positive)
- Correlation between Ranks (RII) and Relative Weight (WAM) : 0.90 (negative)

Assignment of Weight Parameter (Wi) to various CSC and Major Attributes

Attributes	Particulars	Avg. Rating	WSR	RII	Rank	WAM	Relative Weight	Total Attribute Weight
Contracting Companies Attributes	Age of Company	2.722	3	0.545	36.50	50	0.015	**0.117**
	Familiarity with the regulating Authorities	2.667	3	0.534	38.00	50	0.015	
	Familiarity with local Working Culture	2.556	3	0.512	39.00	50	0.015	
	Health & Safety Records of the Company	3.056	2	0.612	34.00	75	0.022	
	Achievement of the Quality Level	4.389	1	0.878	4.00	100	0.029	
	Past Failures	3.833	2	0.767	25.50	75	0.022	

Assignment of Weight Parameter (Wi) to various CSC and Major Attributes

Attributes	Particulars	Avg. Rating	WSR	RII	Rank	WAM	Relative Weight	Total Attribute Weight
Past Performance of the Contractor	Type & Scale of the project Completed in last 03 years	4.222	1	0.845	10.50	100	0.029	**0.204**
	Quality of work in past project	4.111	1	0.823	15.00	100	0.029	
	Percent of previous work completed on schedule	3.944	2	0.789	23.00	75	0.022	
	Standards of subcontractor work in past projects	4.111	1	0.823	15.00	100	0.029	
	Attitude towards correcting faulty works	2.778	3	0.556	35.00	50	0.015	
	Good relationship with past project owners	2.389	3	0.478	41.00	50	0.015	
	Relationship - sub contractors	3.500	2	0.700	29.50	75	0.022	
	Relationship – suppliers	3.444	2	0.689	31.00	75	0.022	
	Relationship - regulating Authorities	3.333	2	0.667	32.00	75	0.022	

Assignment of Weight Parameter (Wi) to various CSC and Major Attributes

Attributes	Particulars	Avg. Rating	WSR	RII	Rank	WAM	Relative Weight	Total Attribute Weight
Financial Capabilities	Current Commitments	3.111	2	0.623	33.00	75	0.022	**0.153**
	Working Capital	4.278	1	0.856	7.00	100	0.029	
	Current & Fixed Assets	3.667	2	0.734	28.00	75	0.022	
	Turnover	3.500	2	0.700	29.50	75	0.022	
	Profit generating Ability of the Company	2.500	3	0.500	40.00	50	0.015	
	Capital Structure of the Company	3.944	2	0.789	23.00	75	0.022	
	Finance Arrangement	3.833	2	0.767	25.50	75	0.022	

Assignment of Weight Parameter (Wi) to various CSC and Major Attributes

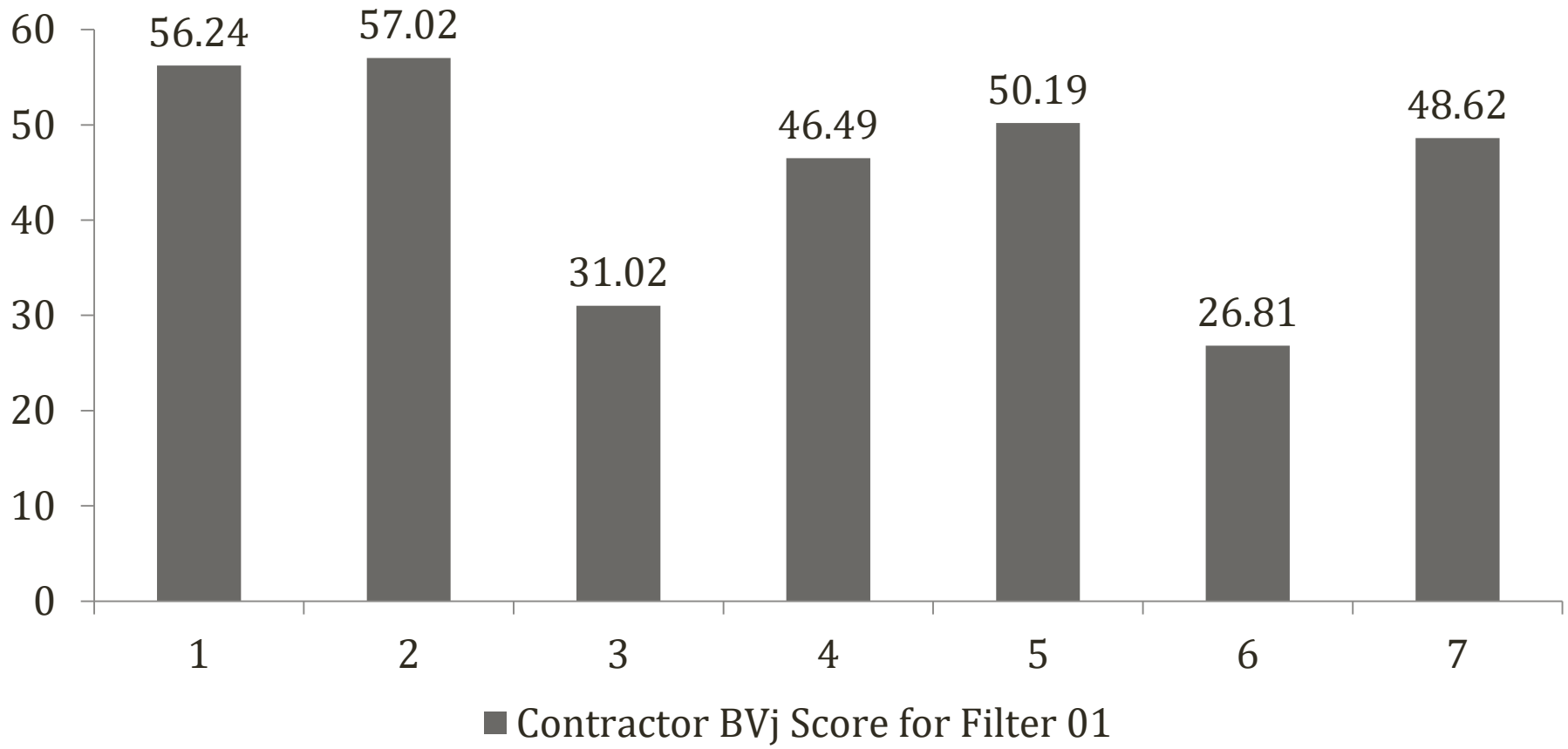
Attributes	Particulars	Avg. Rating	WSR	RII	Rank	WAM	Relative Weight	Total Attribute Weight
Performance Potential of the Contractor	Qualification & Experience of Technical Staff	4.222	1	0.845	10.50	100	0.029	**0.234**
	Qualification & Experience of Management Staff	4.500	1	0.900	3.00	100	0.029	
	Depth of Experience on similar type of project	4.722	1	0.945	1.00	100	0.029	
	Manpower Resources	4.111	1	0.823	15.00	100	0.029	
	Availability of owned construction plant & Equipment	4.000	1	0.800	20.00	100	0.029	
	Present Workload & Capability to support the current project	4.278	1	0.856	7.00	100	0.029	
	Quality Control & Assurance Program	4.667	1	0.934	2.00	100	0.029	
	Specialized knowledge of particular construction method	4.333	1	0.867	5.00	100	0.029	

Assignment of Weight Parameter (Wi) to various CSC and Major Attributes

Attributes	Particulars	Avg. Rating	WSR	RII	Rank	WAM	Relative Weight	Total Attribute Weight
Project Specific Criteria	Construction Method Statement	4.222	1	0.845	10.50	100	0.029	**0.292**
	Proposed project time Schedule	4.000	1	0.800	20.00	100	0.029	
	Qualification & Experience level of project Manager	3.944	2	0.789	23.00	75	0.022	
	Qualification and Experience of professional technical Staffs	4.000	1	0.800	20.00	100	0.029	
	Experience level of project team on similar type of project	4.056	1	0.812	17.50	100	0.029	
	Number of direct workers available for the project	3.722	2	0.745	27.00	75	0.022	
	Availability of testing equipment as quality assurance	4.278	1	0.856	7.00	100	0.029	
	Health & Safety setup for the project	4.056	1	0.812	17.50	100	0.029	
	Checklist available with Contractor	4.222	1	0.845	10.50	100	0.029	
	Estimation Softwares Available with the firm	4.167	1	0.834	13.00	100	0.029	
	Licensed Softwares availability	2.722	3	0.545	36.50	50	0.015	

2. Findings from BVj Model

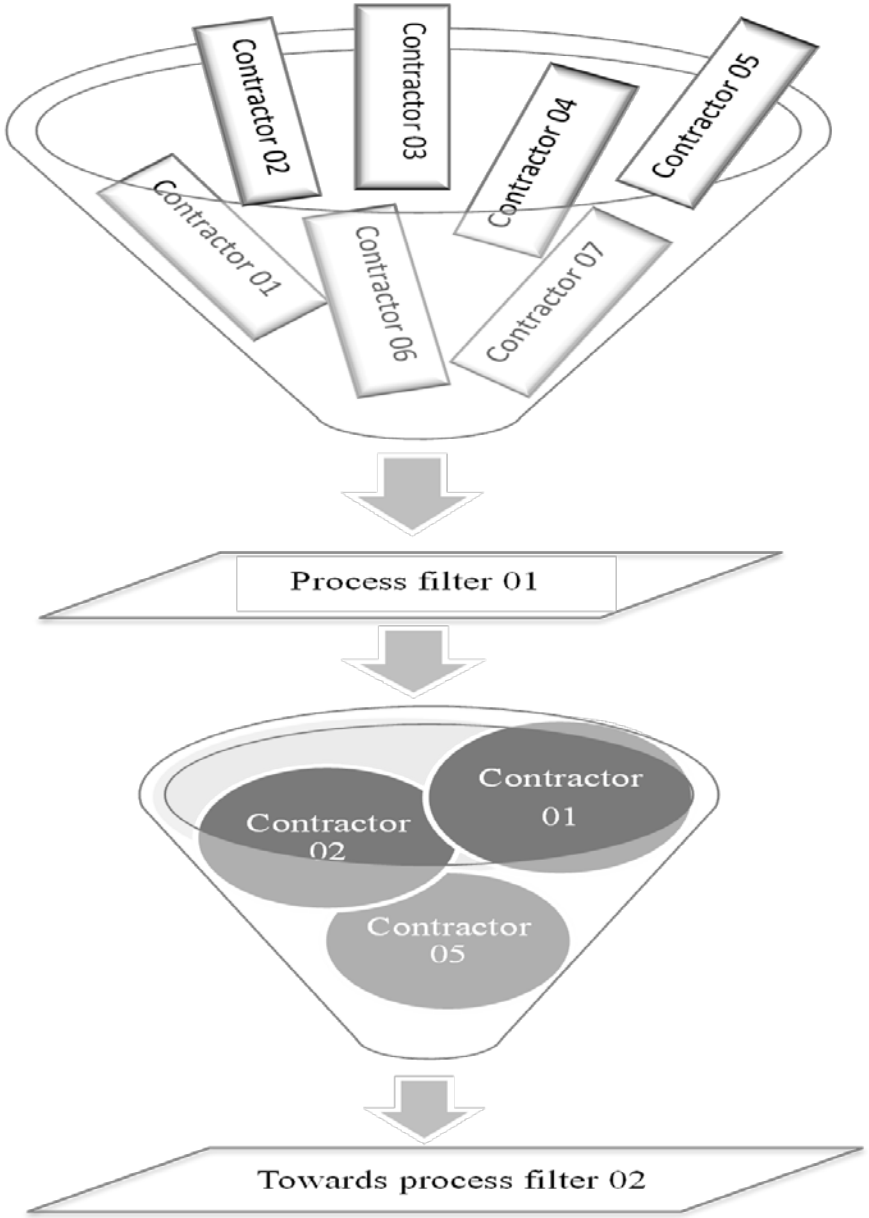
Assignment of W_i & Ps_i for each Response to obtain BV_j



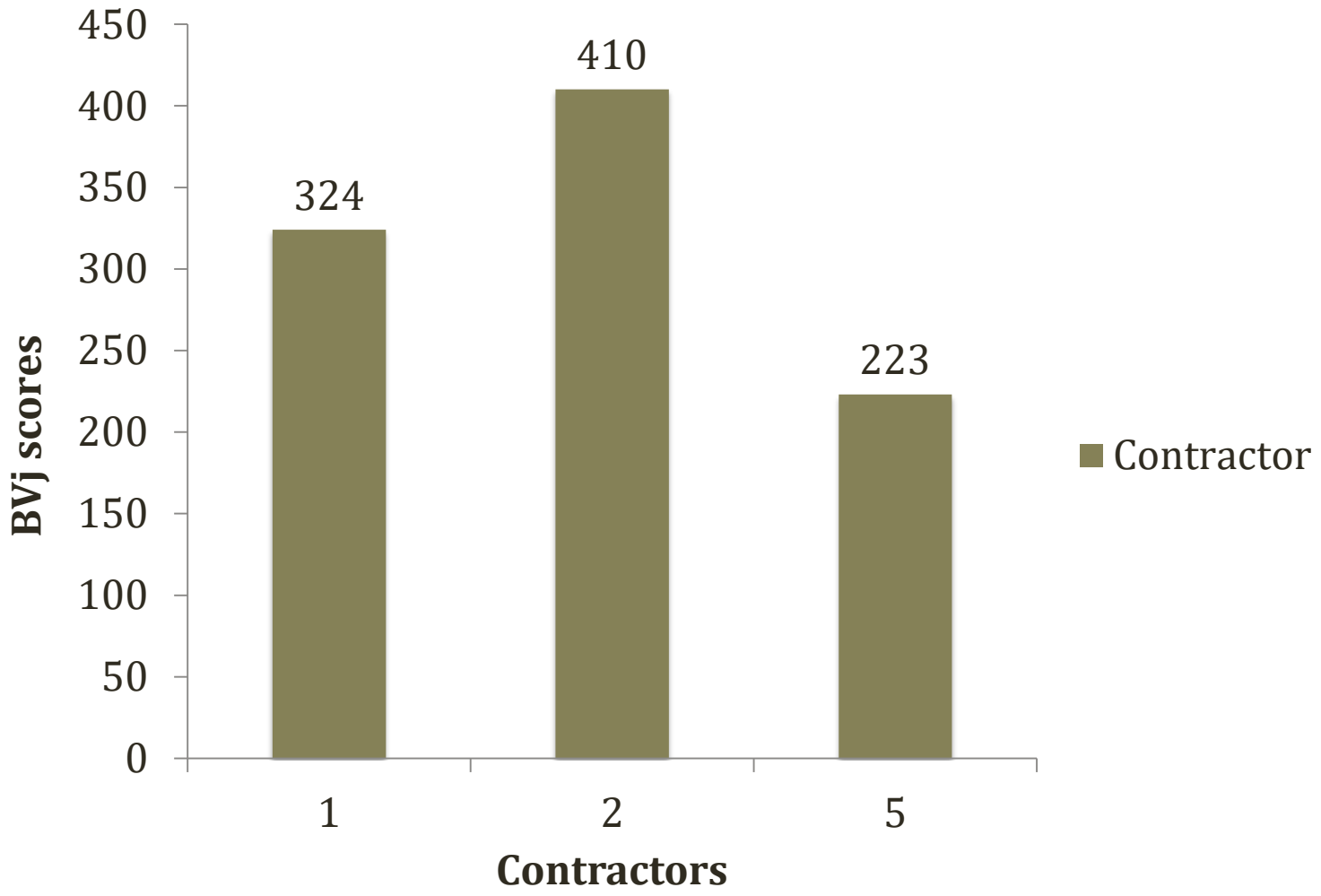
Percentage BVj attainment for each contractor

Contractor	BVj	Percentage BVj Attained	Remark
1	56.237	85%	Selected
2	57.021	86%	Selected
3	31.017	47%	
4	46.494	70%	
5	50.186	76%	Selected
6	26.807	40%	
7	48.616	73%	

Filtration Process



Contractors cost based BVj Score obtained from Filter 03

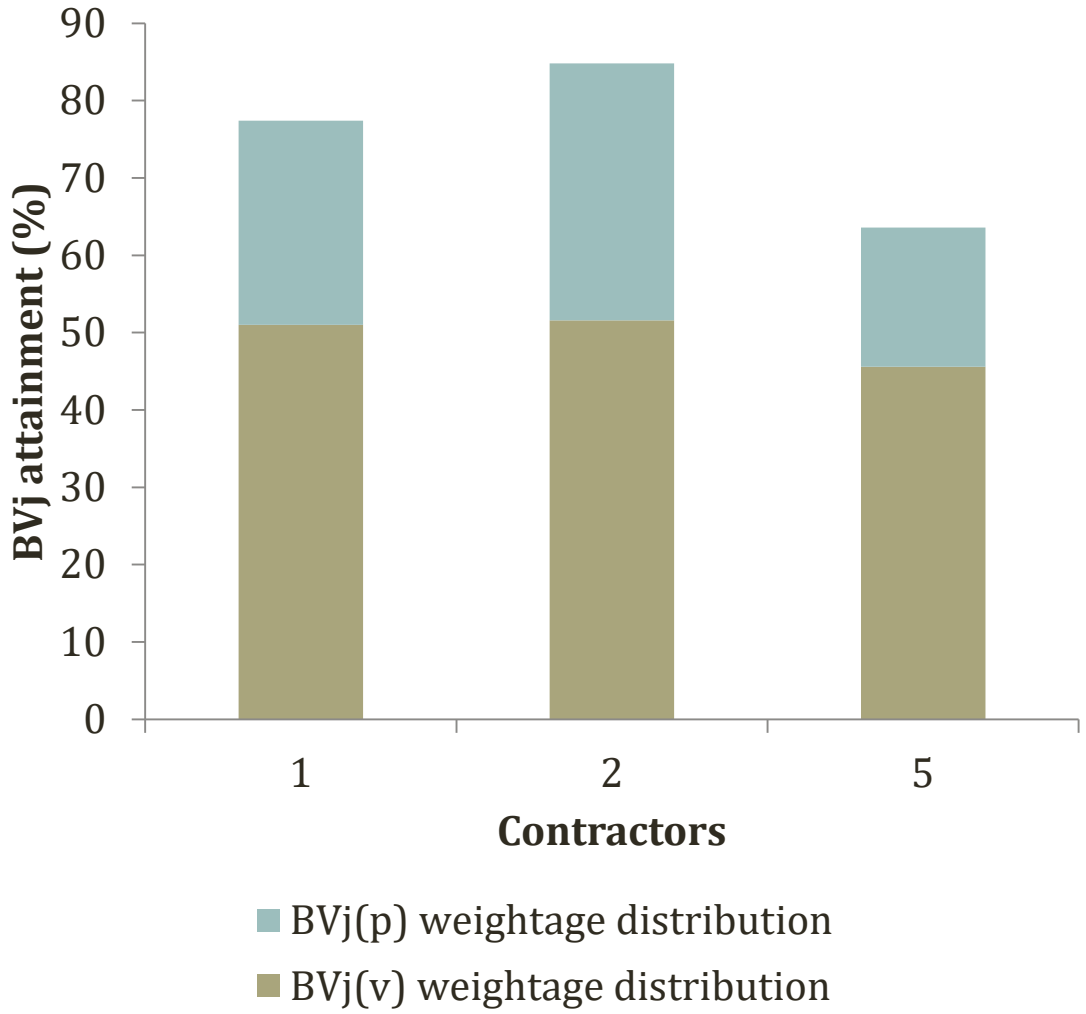


Percentage BVj attainment for each Contractor through Filter 03

Contractor	BVj	Percentage BVj Attained
1	324	66%
2	410	83%
5	223	45%

3. Selection of the Contractor based on score

Contractor	BVj(v)	BVj(p)	Total BVj Attainment
1	85%	66%	77%
2	86%	83%	85%
5	76%	45%	64%



4. Findings from Six sigma model

- Defects per million Opportunities (DPMO) (Han et al. 2008)

$$DPMO = \frac{(No.of\ Defects\ in\ data\ assessment\ sheet)}{No.of\ Opportunities\ of\ defects \times No.of\ Units} \times 1{,}000{,}000 \quad \text{...Eq (4)}$$

- Overview of Sigma Levels & DPMO

Yield	DPMO	Sigma Level
30.9	6,90,000	1
69.2	3,08,000	2
93.3	66,800	3
99.4	6,210	4
99.98	320	5
99.9997	3.4	6

Sigma Level Calculation

Sr.no	No. of Units Observed	Defects observed in Assessment Sheet	Opportunities	DPMO	Sigma Level
1	Unit 1	7.00	45	11265. 43	3.8
2	Unit 2	12.00	45		
3	Unit 3	6.00	45		
4	Unit 4	3.00	45		
5	Unit 5	6.00	45		
6	Unit 6	4.00	45		
7	Unit 7	2.00	45		
8	Unit 8	9.00	45		
9	Unit 9	4.00	45		
10	Unit 10	9.00	45		
11	Unit 11	5.00	45		
12	Unit 12	6.00	45		
Total	**12**	**73.00**	**540**		**Yield: 98.18%**

Conclusion

- The best value model can be used to predict the suitable contractor for execution work.
- Filtration process helps to define -
  - The project specific characteristics at the initial phase of construction.
  - Take financial risk into account.
  - Transfer of project responsibility
  - Quantity and cost estimation
  - Identify work flow, pre- scheduling project.

Conclusion

- Using RII and WAM models helps to classify the highest weighing attributes.
- Selecting Best value contractor, helps eliminating construction waste.
- Six Sigma models helps in successful validation of Best value technique.

Scope for Future work

- The studied model proved to be reasonable and feasible, and showed a satisfactory performance.
- Further work is required to develop a soft computed generalised project based model. which will carry a complete regional database of contractors and vendors.
- Also the weighted scale can be developed by Analytic Hierarchy Model, Multi-criteria model and compared with the current system of ranking.
- A generalised relation can be developed among the major CSC attributes and a relationship can be developed among various parametric variables.

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List of Publications

International Journals

"Practical Approach to Construction Industry using Best Value and Six Sigma Techniques", Journal of Construction Engineering and Management, ASCE (Communicated – June, 2017).

National Journals

"An application of Best value system in Construction Industry: A State of Art", Nicmar- Journal of Construction Management, Nicmar Publications (Communicated – March, 2017).

Thank You…