



College of Performance Management

EVM World 2017

SAND2017-5410C

Title: EVM Research: Guiding the Future

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Learning Objectives

- Understand where EVMS research is being conducted and where the research is being published
- Understand the primary focus areas of EVMS research over the past 20 years

EVM Research: Guiding the Future

- Agenda
 - Methodology
 - Who, What, When, Where
 - EVM Research Summary – By Grouping
 - Forecasting
 - Control
 - Extensions
 - Implementation
 - Other
 - Observations
 - Conclusion

METHODOLOGY

Methodology

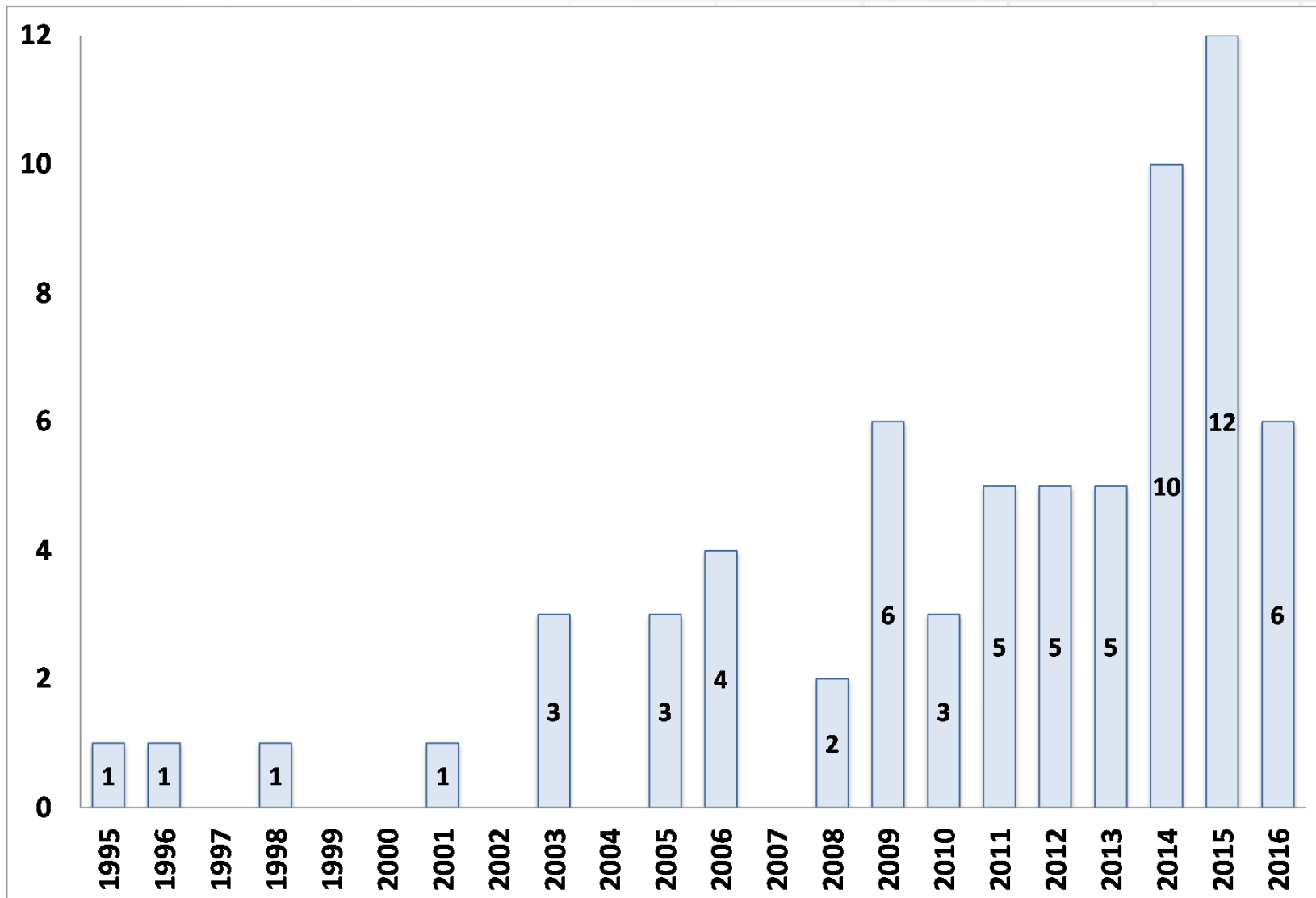
- Article selection
 - Search of EBESCO and Science Direct databases
 - Keyword/Abstract – Earned Value
 - Peer reviewed journals
 - Article count - 94
 - Eliminated articles not listed in Cabell's Directory of Publishing Opportunities
 - Strict criteria for inclusion
 - Final article count - 68

Methodology (continued)

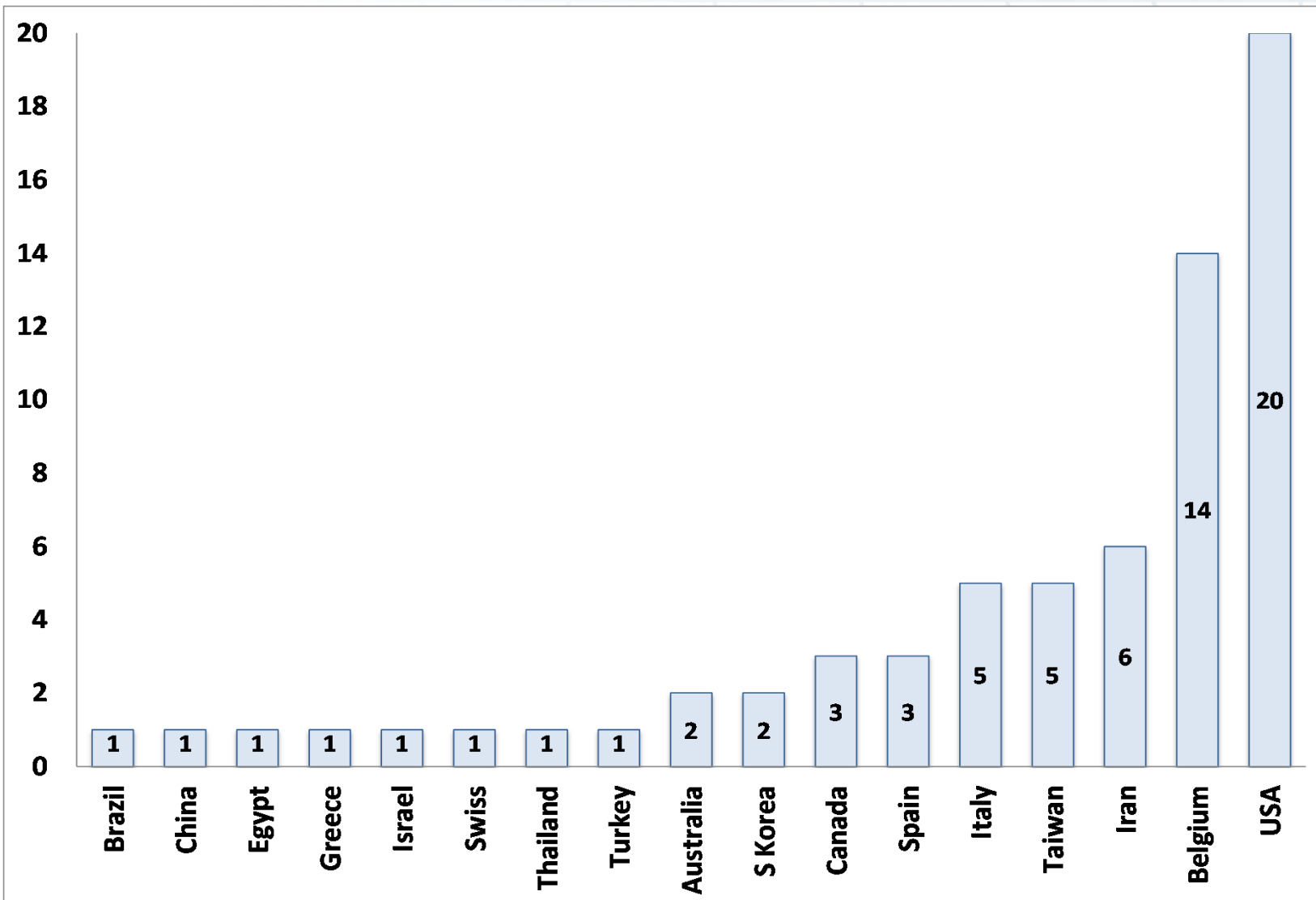
- Article grouping
 - Identified primary topic
 - Forecasting – 25 articles (37%)
 - Includes articles on CPI stability
 - Control – 12 articles (18%)
 - Extensions – 10 articles (15%)
 - Implementation – 6 articles (9%)
 - Other – 15 articles (22%)
 - References
 - Bibliography sorted by grouping
 - References included on individual charts when a specific article is referred to

SUMMARY: WHO, WHAT, WHEN, WHERE

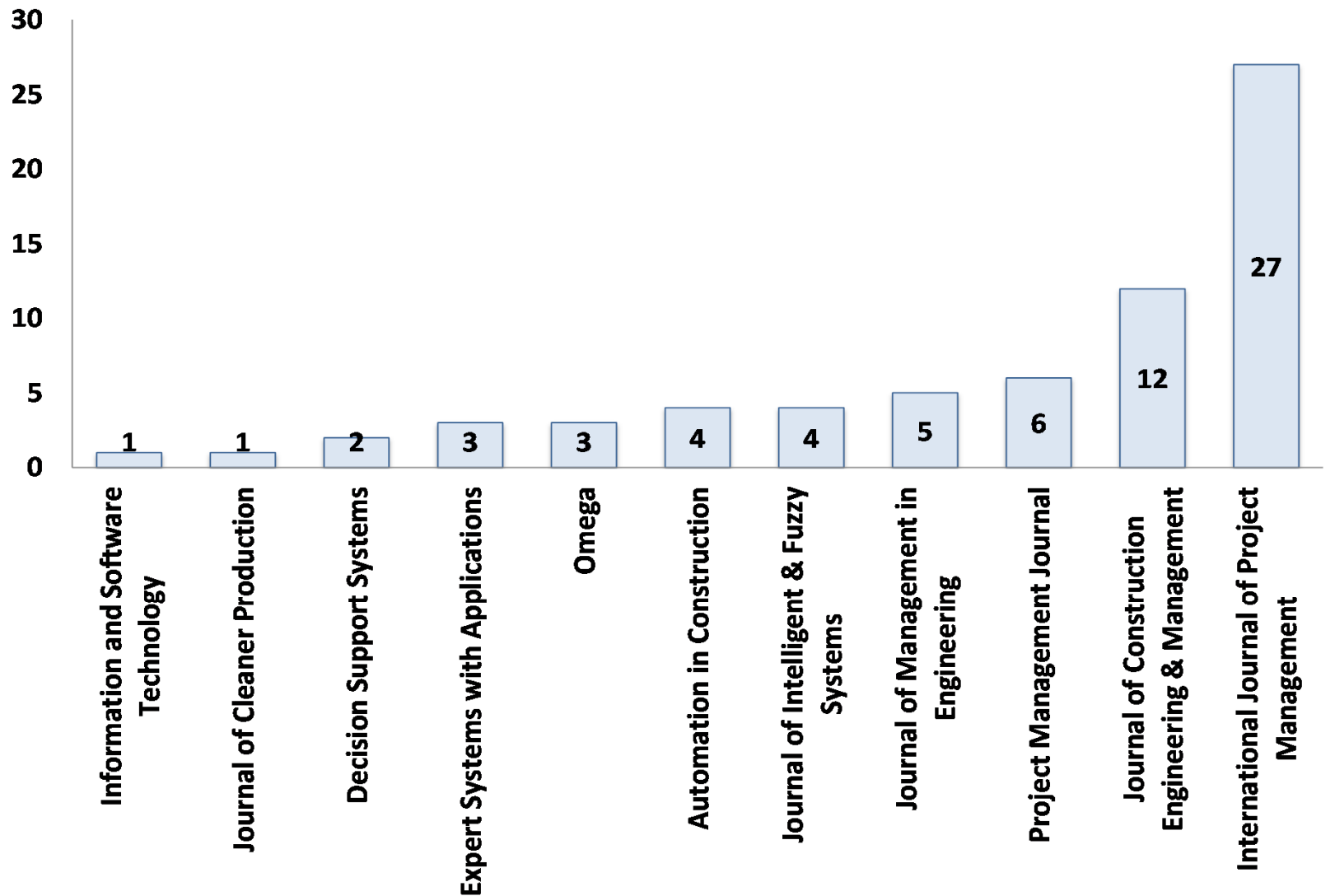
Articles by Year



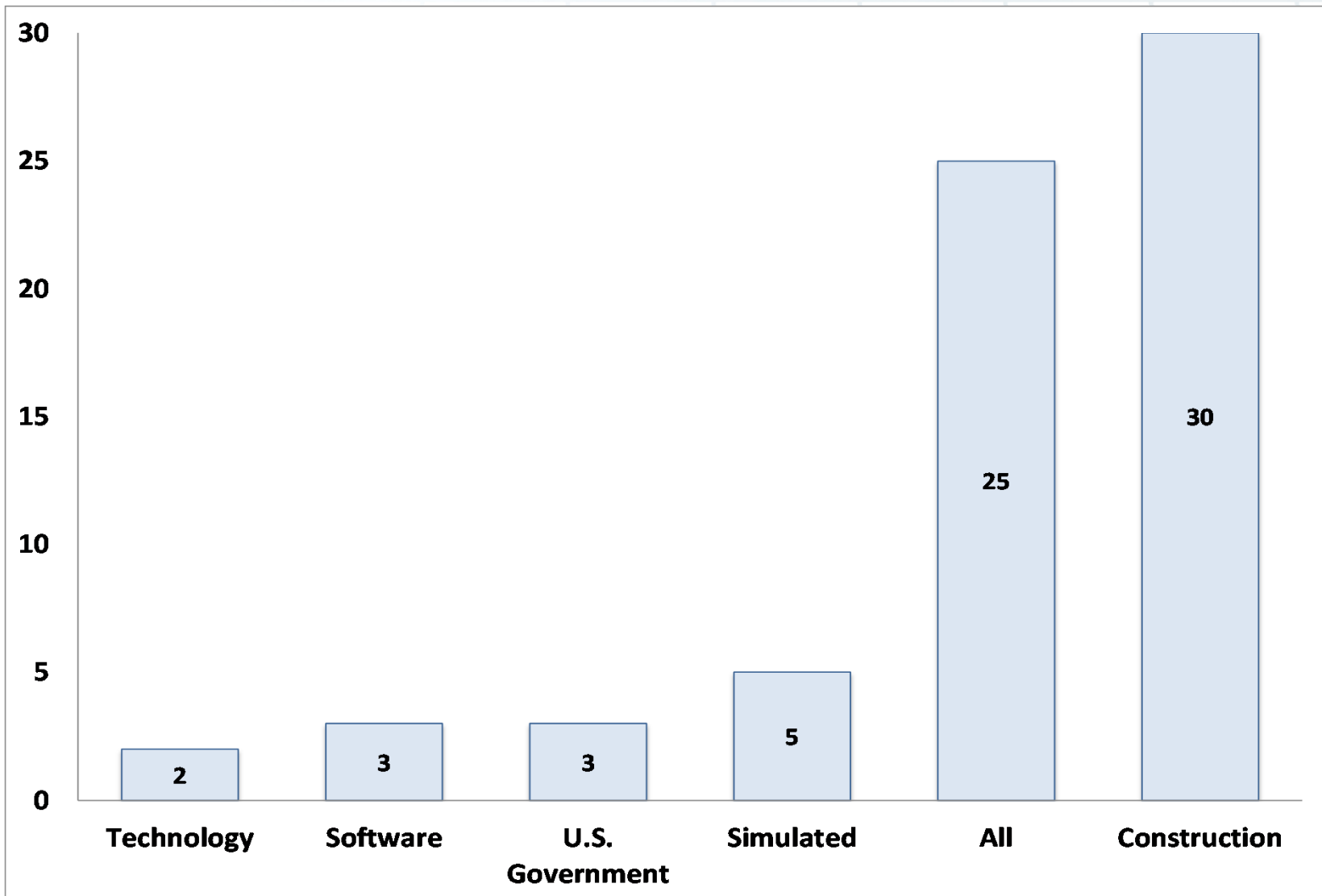
Articles by Country



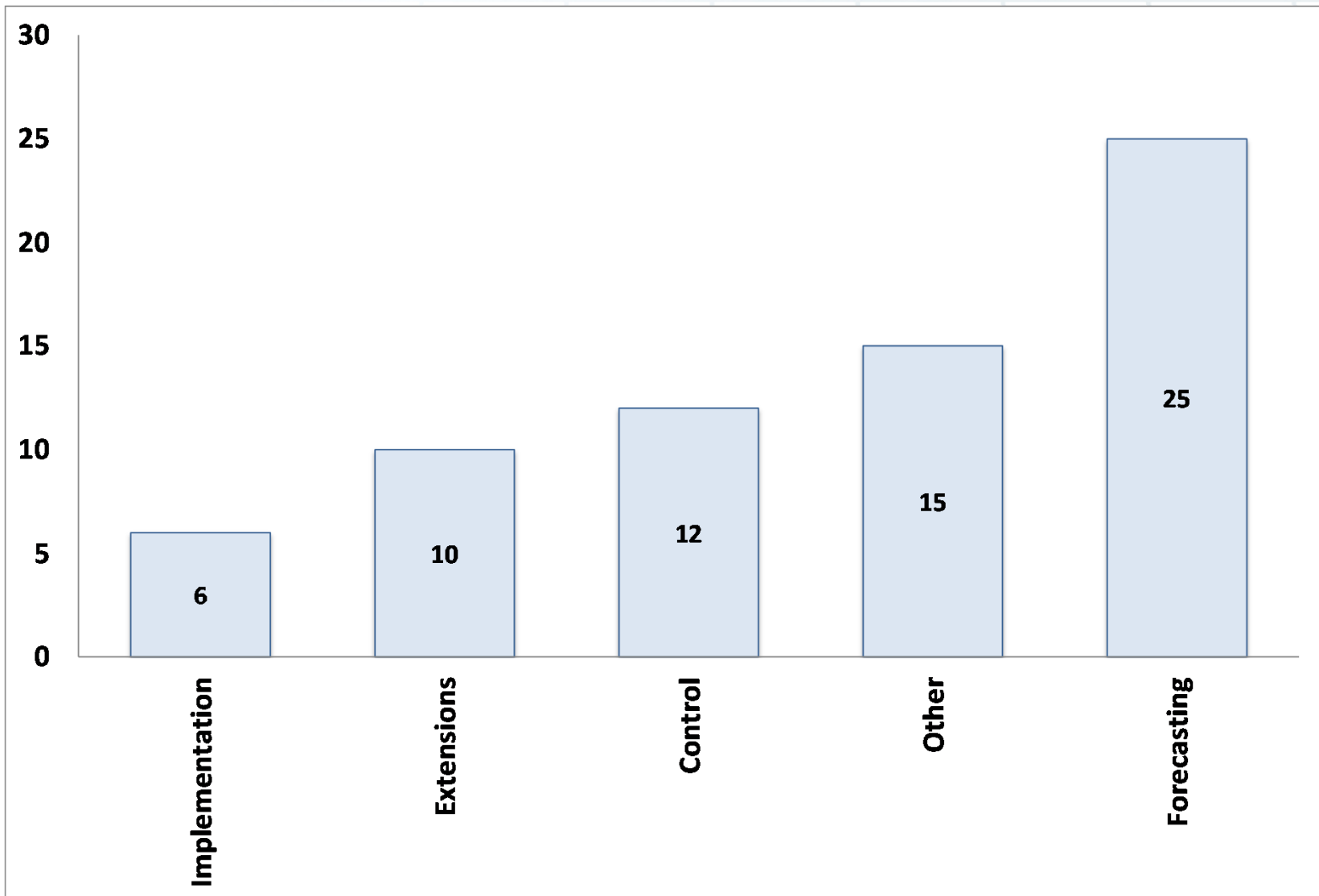
Articles by Journal



Articles by Project Type



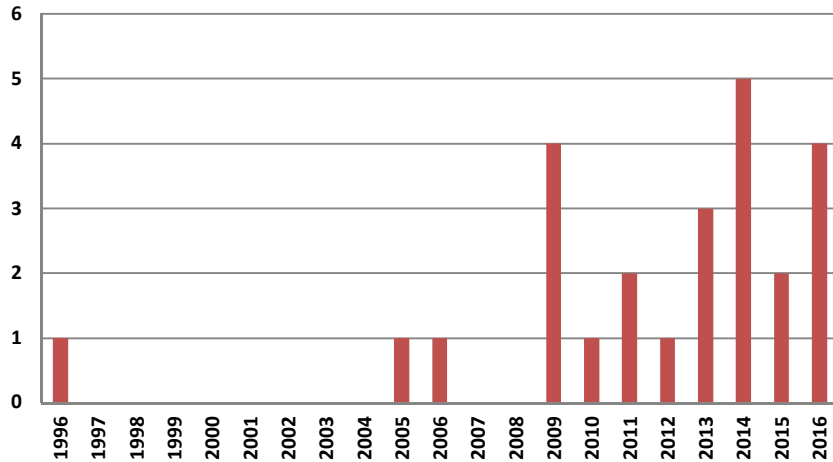
Articles by Grouping



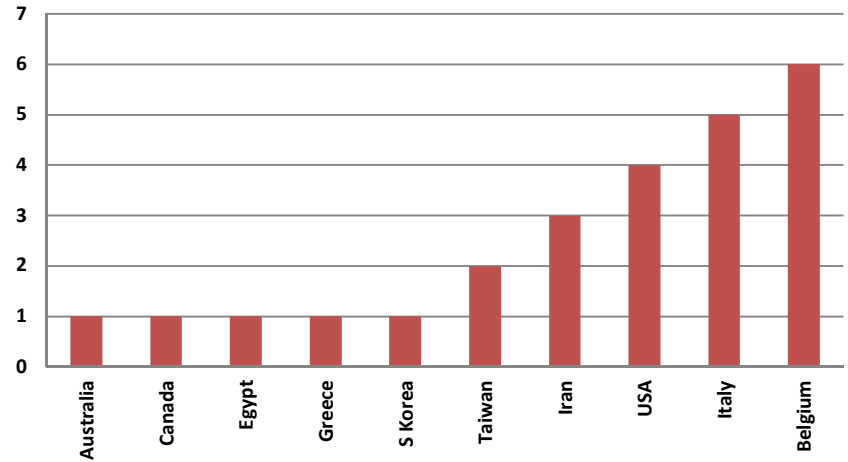
RESEARCH SUMMARY – BY GROUPING

Forecasting – Summary

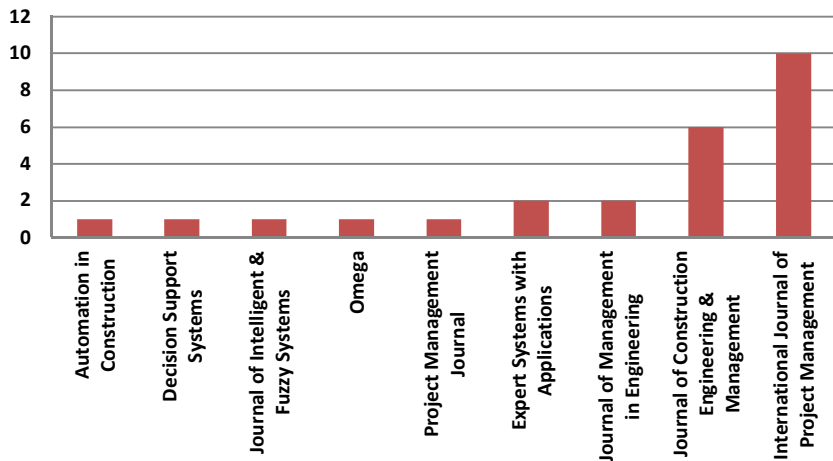
Articles by Year



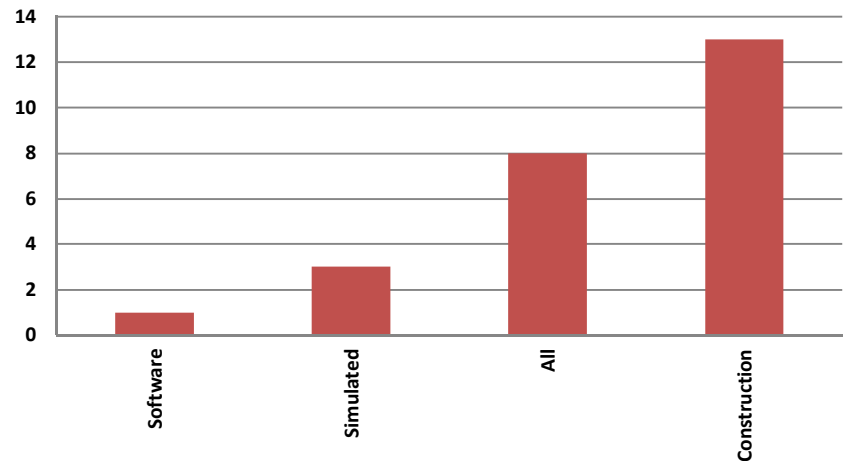
Articles by Country



Articles by Journal



Articles by Project Type



Forecasting –CPI-Based Forecasts

- CPI Stability
 - CPI Research on large, long duration DOD-type projects
 - Once project is 20% complete, the final CPI will be within 20% of cum to date CPI (¹Christensen & Payne)
 - More current research on small to medium size projects with short to medium duration (Lipke, Zwikael, Henderson, Anbari, 2009)
 - CPI takes longer to stabilize, or
 - CPI may not stabilize at all
- CPI-based forecasts provide point estimates & do not account for variability in project

¹Christensen, D., & Payne, K. (1992). Cost performance index stability-Fact or fiction. *Journal of Parametrics*, 10, 27-40.

Forecasting – Overview

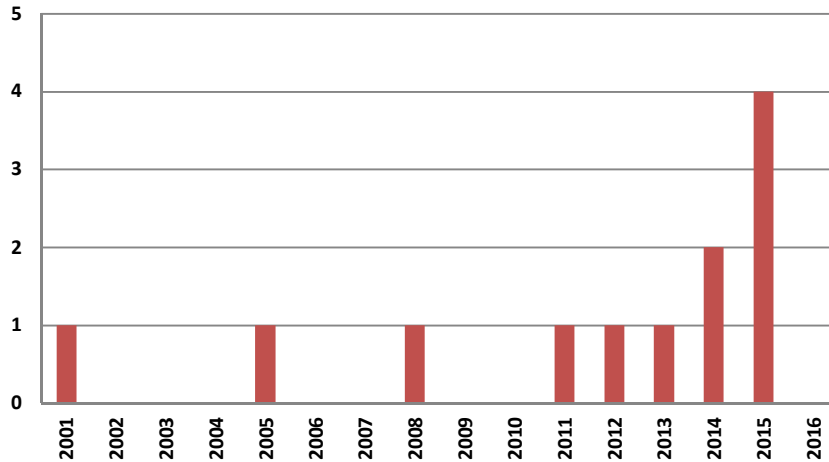
- Establishing confidence limits for forecasts
- Improvement of PV to improve predictive power of AC & EV
 - Linear models
 - Learning curves
- Application of sensitivity measures to schedule forecasts (Elshaer, 2013)
- Use of statistical models to improve cost and schedule forecasts
 - requiring varying levels of mathematical/statistical skills
- Comparison of accuracy & timeliness of EVM, ES, and EDM duration forecasting methodologies (Batselier & Vanhoucke, 2015)

Forecasting – Statistical Forecasts

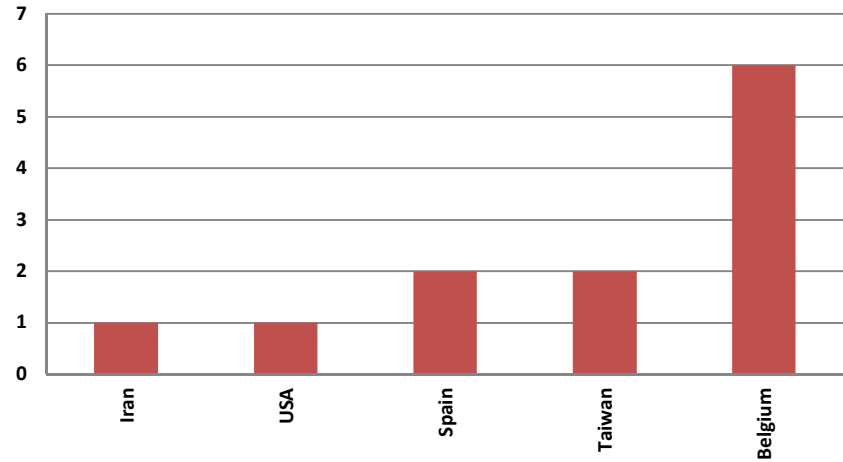
	2009	2010	2011	2012	2013	2014	2015	2016
Logistic Model	De Marco, Briccarello & Rafele							
Nonlinear Regression						Narbaev & De Marco (a); Narbaev & De Marco (b)		
Multivariate Regression								Vanhoucke, Colin
Bayesian Model	Kim & Reinschmidt	Kim & Reinschmidt	Kim & Reinschmidt		Caron, Ruggeri & Merli			Caron, Ruggeri & Pierini
Fuzzy Numbers			Naeni & Salehipour	Maravas & Pantouvakis	Mortaji, Bagherpour, Noori	Naeni, Shadrokh & Salehipour		
Artificial Intelligence						Wauters & Vanhoucke		Wauters & Vanhoucke

Control – Summary

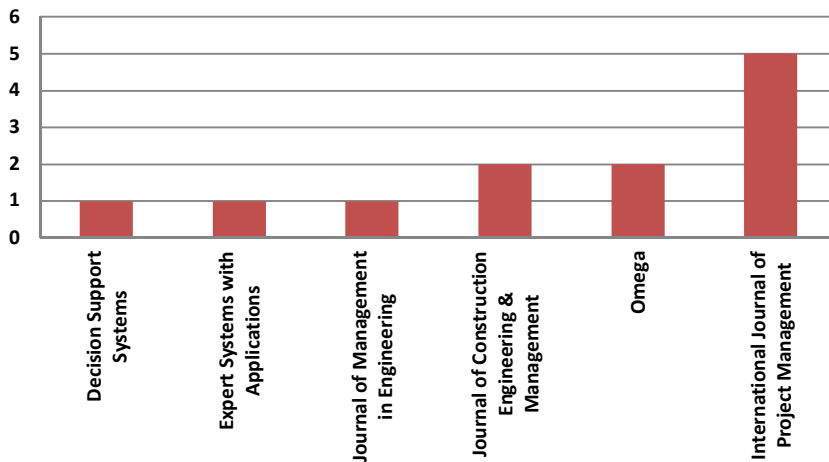
Articles by Year



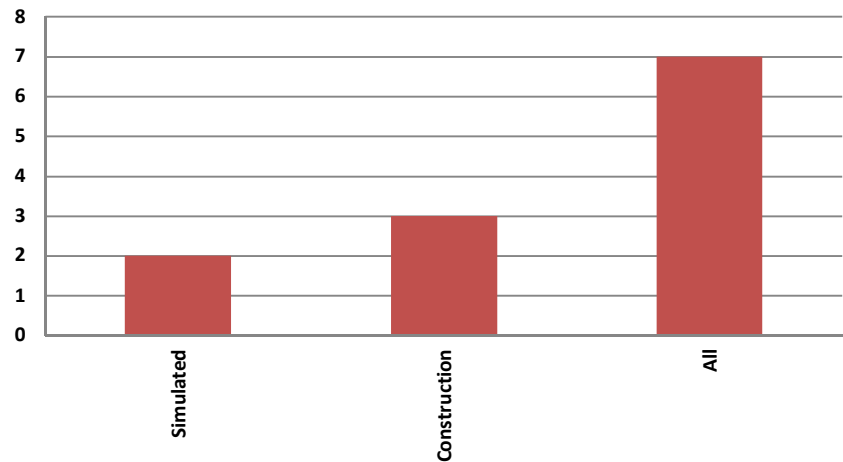
Articles by Country



Articles by Journal



Articles by Project Type

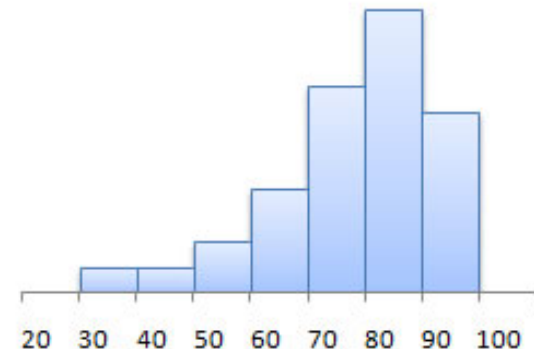


Control – Project Variability

- How much of a performance variance is due to normal variation on the project and how much is due to a real issue?
 - Forecasting methods to identify range of anticipated performance by time
 - Statistical Process Control (SPC) techniques
 - What control methods are appropriate based on schedule topology (Vanhoucke, 2011)

Control – SPC Charts

- Uses quality management tools to identify when metrics are out of control
- SPI / CPI are not normally distributed ¹
 - Typically skew to the right
 - Transformations required to approximate a normal distribution
 - Use six-sigma tools to perform transformations and build control charts



¹Lipke, Walt. 2011. Further Study of the Normality of CPI and SPI(t)

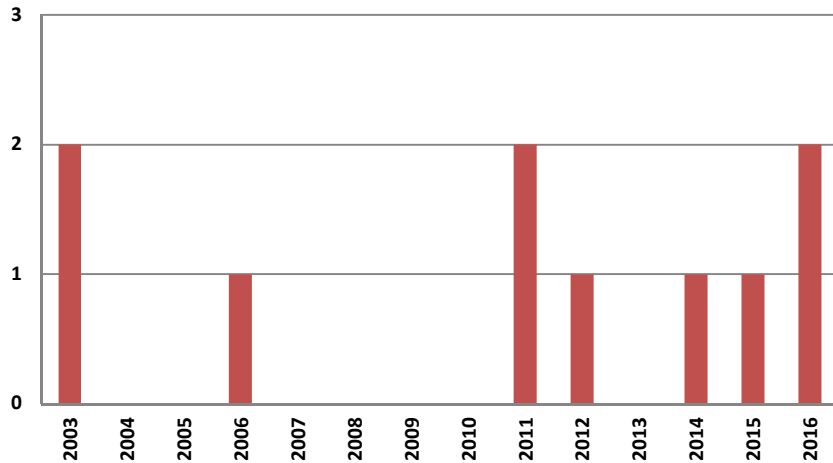
Control: Top down vs Bottom Up

- Top down
 - EVM
 - Manage by exception
 - Most appropriate on projects with serial topology
- Bottoms up
 - Schedule risk assessment (SRA)
 - Detail schedule analysis at work package level
 - Most appropriate on projects with parallel topology

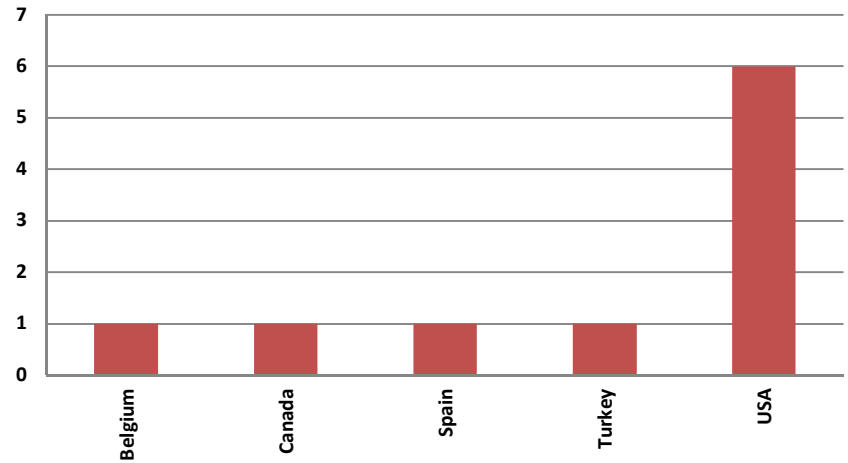
(Vanhoucke, 2011)

Extensions – Summary

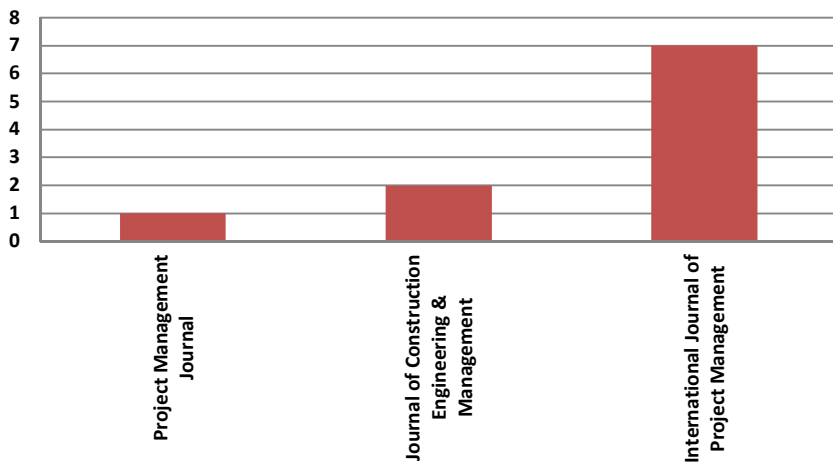
Articles by Year



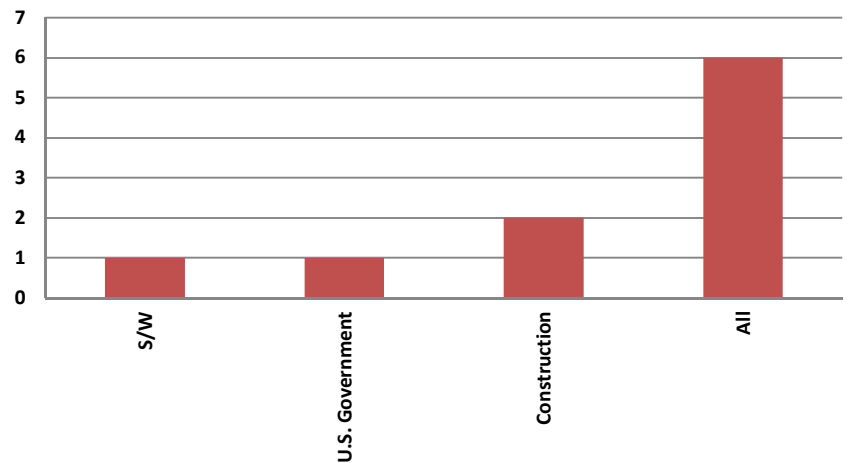
Articles by Country



Articles by Journal



Articles by Project Type



Extensions

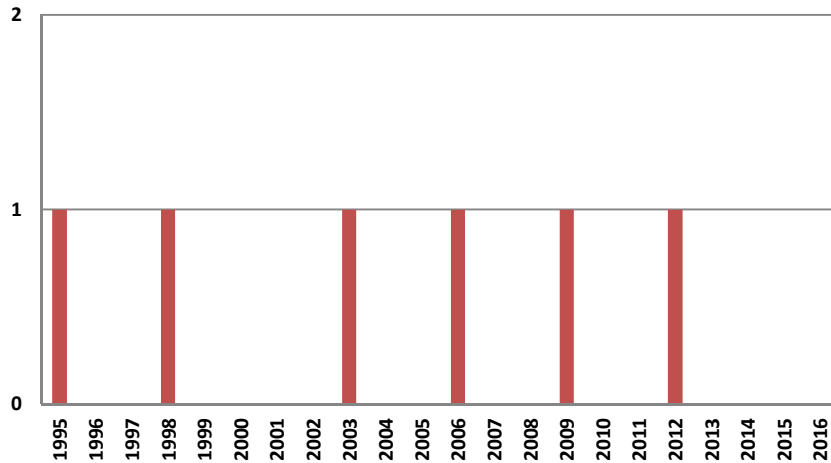
- Introduces new metrics or new ways of designating old metrics
 - Earned Duration Management (EDM) (Khamooshi & Golafshani, 2014)
 - Theoretical basis for Earned Schedule (ES) (Warburton & Cioffi, 2016)
 - Combining earned value analysis with other project attributes to develop new metrics – risk, incentives

Lipke, W. H. (2009). *Earned Schedule*.
Lexington, KY: Lulu Publishing.

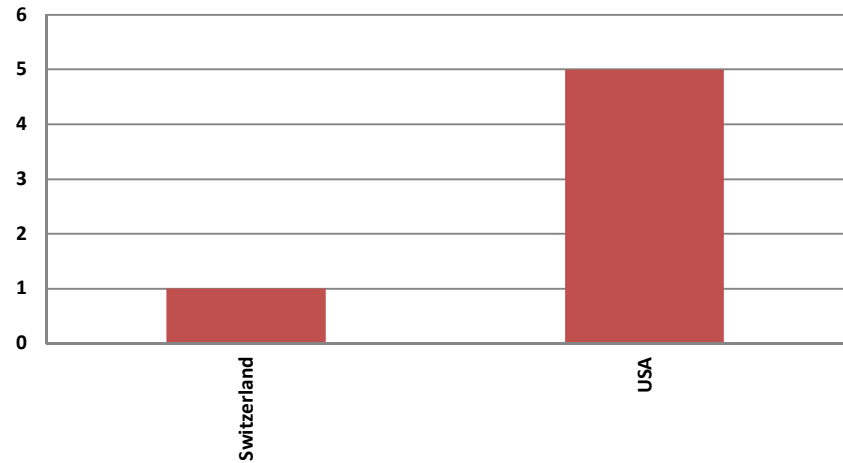
<http://www.earnedschedule.com/>

Implementation – Summary

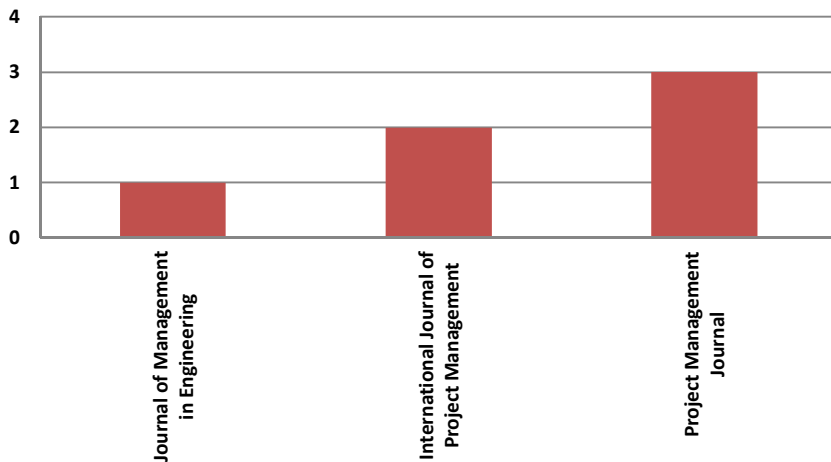
Articles by Year



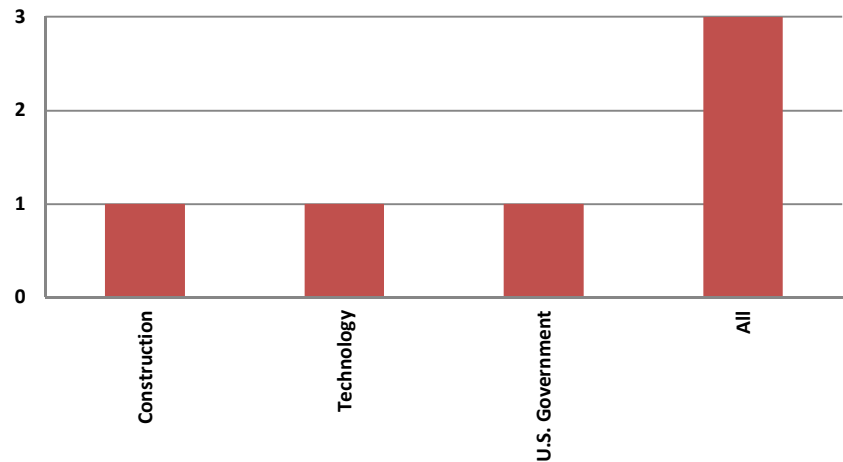
Articles by Country



Articles by Journal



Articles by Project Type

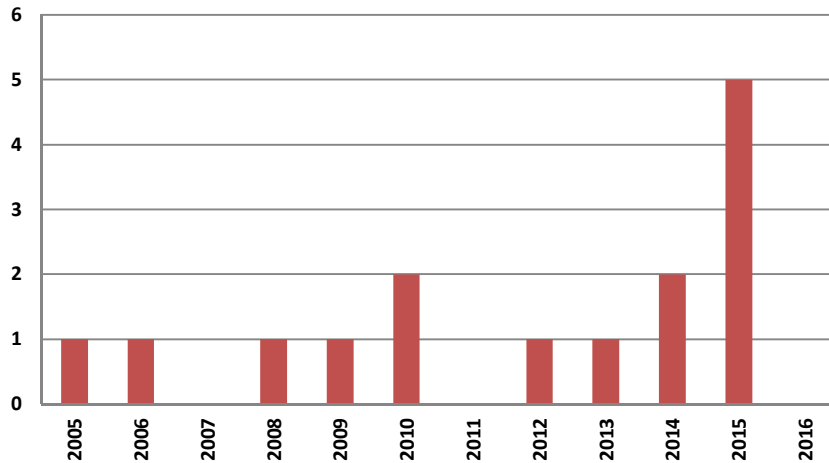


Implementation

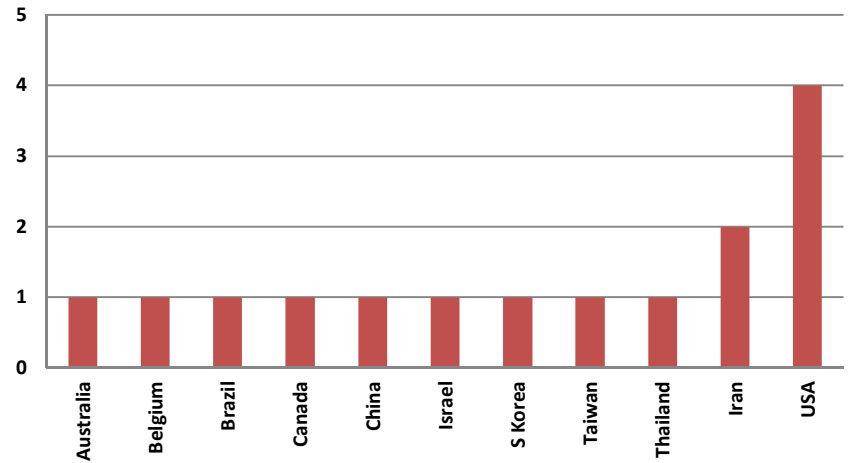
- Generally case studies
 - Large Hadron Collider (Bonnal, Jonghe, & Ferguson, 2006)
 - NASA implementation of EVMS (Kwak & Anbari, 2009, 2012)
- Recommendations for faster, better, cheaper implementations of EV or implementations of EV on specific project types

Other – Summary

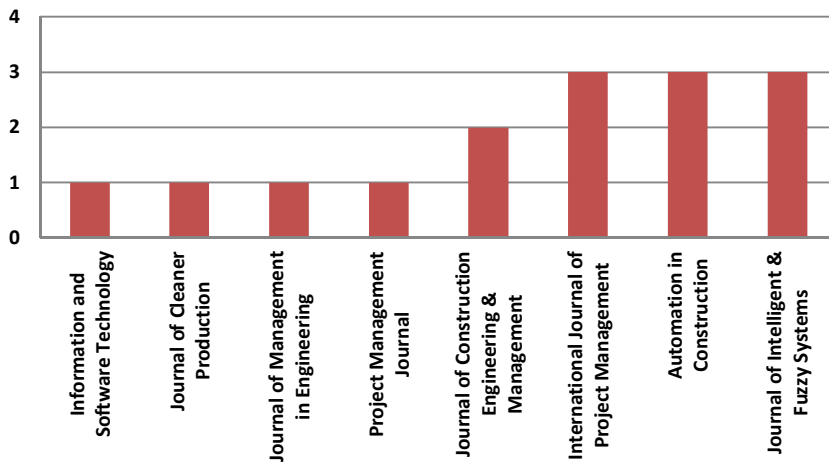
Articles by Year



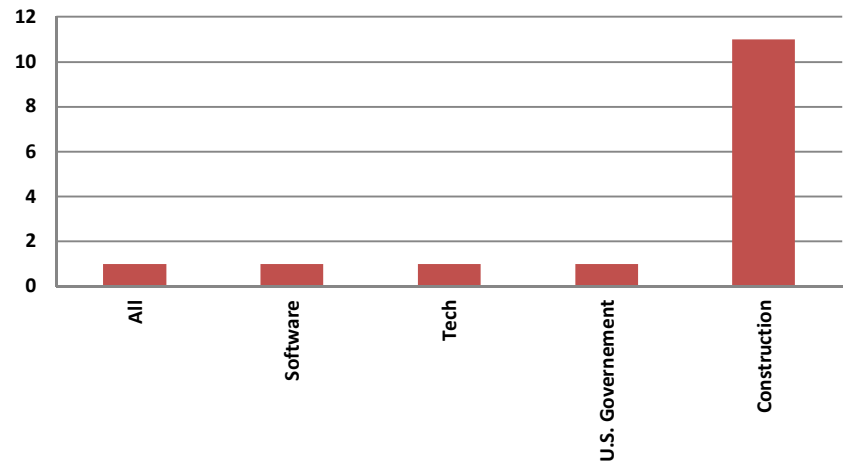
Articles by Country



Articles by Journal



Articles by Project Type



Other

- Literature review and classification of 187 articles on EV and project controls (Willems & Vanhoucke, 2015)
- Reporting tools
- EV game, DELIVER! Federal University Brazil (von Wangenheim, Savi, & Borgatto, 2012)
- Advance tools to track construction progress
- Tracking CO² emissions as part of the EV process (Kim, Kim, Hong & Park (2015)

OBSERVATIONS

Observations

- Small sample size
- Larger sample size for simulated projects – small number of tasks
- Research from a technical perspective – not social
- Data quality assumed
- Duration forecast using Earned Schedule (ES)
 - Comparisons of EV, Earned duration management, and ES duration forecasts showed that ES gave most consistent and accurate forecasts

Conclusion

- Methodology
- Who/What/When/Where
- EV research
 - Forecasting
 - Control
 - Extensions
 - Implementation
 - Other
- Observations

Questions???

Bibliography

- Forecasting

Batselier, J., & Vanhoucke, M. (2015). Evaluation of deterministic state-of-the-art forecasting approaches for project duration based on earned value management. *International Journal of Project Management*, 33(7), 1588-1596. doi: 10.1016/j.ijproman.2015.04.003

Caron, F., Ruggeri, F., & Pierini, B. (2016). A Bayesian approach to improving estimate to complete. *International Journal of Project Management*, 34(8), 1687-1702. doi: 10.1016/j.ijproman.2016.09.007

Chen, H. L., Chen, W. T., & Lin, Y. L. (2016). Earned value project management: Improving the predictive power of planned value. *International Journal of Project Management*, 34(1), 22-29. doi: 10.1016/j.ijproman.2015.09.008

Elshaer, R. (2013). Impact of sensitivity information on the prediction of project's duration using earned schedule method. *International Journal of Project Management*, 31(4), 579-588. doi: 10.1016/j.ijproman.2012.10.006

Kim, B.-C., & Reinschmidt, K. F. (2009). Probabilistic forecasting of project duration using Bayesian Inference and the Beta Distribution. *Journal of Construction Engineering & Management*, 135(3), 178-186. doi: 10.1061/(ASCE)0733-9364(2009)135:3(178)

Kim, B.-C., & Reinschmidt, K. F. (2011). Combination of project cost forecasts in earned value management. *Journal of Construction Engineering & Management*, 137(11), 958-966. doi: 10.1061/(ASCE)CO.1943-7862.0000352

Bibliography (Continued)

- Forecasting

Maravas, A., & Pantouvakis, J.-P. (2012). Project cash flow analysis in the presence of uncertainty in activity duration and cost. *International Journal of Project Management*, 30(3), 374-384. doi: 10.1016/j.ijproman.2011.08.005

Naeni, L. M., & Salehipour, A. (2011). Evaluating fuzzy earned value indices and estimates by applying alpha cuts. *Expert Systems with Applications*, 38(7), 8193-8198. doi: 10.1016/j.eswa.2010.12.165

Narbaev, T., & de Marco, A. (2014a). Combination of growth model and earned schedule to forecast project cost at completion. *Journal of Construction Engineering & Management*, 140(1), -1-10. doi: 10.1061/(ASCE)CO.1943-7862.0000783

Park, H. K., Han, S. H., & Russell, J. S. (2005). Cash flow forecasting model for general contractors using moving weights of cost categories. *Journal of Management in Engineering*, 21(4), 164-172. doi: 10.1061/(ASCE)0742-597X(2005)21:4(164)

Vandevoorde, S., & Vanhoucke, M. (2006). A comparison of different project duration forecasting methods using earned value metrics. *International Journal of Project Management*, 24(4), 289-302. doi: 10.1016/j.ijproman.2005.10.004

Wauters, M., & Vanhoucke, M. (2014). Support Vector Machine Regression for project control forecasting. *Automation in Construction*, 47, 92-106. doi: 10.1016/j.autcon.2014.07.014

Wauters, M., & Vanhoucke, M. (2016). A comparative study of Artificial Intelligence methods for project duration forecasting. *Expert Systems with Applications*, 46, 249-261. doi: 10.1016/j.eswa.2015.10.008

Bibliography (Continued)

- Control

Acebes, F., Pajares, J., Galán, J. M., & López-Paredes, A. (2014). A new approach for project control under uncertainty. Going back to the basics. *International Journal of Project Management*, 32(3), 423-434. doi: 10.1016/j.ijproman.2013.08.003

Aliverdi, R., Moslemi Naeni, L., & Salehipour, A. (2013). Monitoring project duration and cost in a construction project by applying statistical quality control charts. *International Journal of Project Management*, 31(3), 411-423. doi: 10.1016/j.ijproman.2012.08.005

Colin, J., & Vanhoucke, M. (2014). Setting tolerance limits for statistical project control using earned value management. *Omega*, 49, 107-122. doi: 10.1016/j.omega.2014.06.001

Colin, J., & Vanhoucke, M. (2015). Developing a framework for statistical process control approaches in project management. *International Journal of Project Management*, 33(6), 1289-1300. doi: 10.1016/j.ijproman.2015.03.014

Leu, S.-S., & Lin, Y.-C. (2008). Project performance evaluation based on statistical process control techniques. *Journal of Construction Engineering & Management*, 134(10), 813-819. doi: 10.1061/(ASCE)0733-9364(2008)134:10(813)

Vanhoucke, M. (2011). On the dynamic use of project performance and schedule risk information during project tracking. *Omega*, 39(4), 416-426. doi: 10.1016/j.omega.2010.09.006

Bibliography (Continued)

- Extensions

Anbari, F. T. (2003). Earned value project management method and extensions. Project Management Journal, 34(4), 12-23.

Hanna, A. S. (2012). Using the earned value management system to improve electrical project control. Journal of Construction Engineering & Management, 138(3), 449-457. doi: 10.1061/(ASCE)CO.1943-7862.0000426

Hegazy, T., & Petzold, K. (2003). Genetic optimization for dynamic project control. Journal of Construction Engineering & Management, 129(4), 396.

Khamooshi, H., & Golafshani, H. (2014). EDM: Earned Duration Management, a new approach to schedule performance management and measurement. International Journal of Project Management, 32(6), 1019-1041. doi: 10.1016/j.ijproman.2013.11.002

Warburton, R. D. H. (2011). A time-dependent earned value model for software projects. International Journal of Project Management, 29(8), 1082-1090. doi: 10.1016/j.ijproman.2011.02.008

Bibliography (Continued)

- Implementation

Bonnal, P., de Jonghe, J., & Ferguson, J. (2006). A deliverable-oriented evm system suited to a large-scale project. *Project Management Journal*, 37(1), 67-80.

Kim, E., Wells, W. G. J., & Duffey, M. R. (2003). A model for effective implementation of Earned Value Management methodology. *International Journal of Project Management*, 21, 375-382. doi: 10.1016/S0263-7863(02)00049-2\

Kwak, Y. H., & Anbari, F. T. (2009). Analyzing project management research: Perspectives from top management journals. *International Journal of Project Management*, 27(5), 435-446. doi: 10.1016/j.ijproman.2008.08.004

Bibliography (Continued)

- Other

Bashford, H. H., Walsh, K. D., & Sawhney, A. (2005). Production System Loading—Cycle Time Relationship in Residential Construction. *Journal of Construction Engineering & Management*, 131(1), 15-22. doi: 10.1061/(ASCE)0733-9364(2005)131:1(15)

Chou, J.-S., Chen, H.-M., Hou, C.-C., & Lin, C.-W. (2010). Visualized EVM system for assessing project performance. *Automation in Construction*, 19(5), 596-607. doi: 10.1016/j.autcon.2010.02.006

Kim, Y.-W., & Ballard, G. (2010). Management thinking in the earned value method system and the last planner system. *Journal of Management in Engineering*, 26(4), 223-228. doi: 10.1061/(ASCE)ME.1943-5479.0000026

Salari, M., Bagherpour, M., & Kamyabniya, A. (2014). Fuzzy extended earned value management: A novel perspective. *Journal of Intelligent & Fuzzy Systems*, 27, 1393-1406. doi: 10.3233/IFS-131106

Sun, C., Man, Q., & Wang, Y. (2015). Study on BIM-based construction project cost and schedule risk early warning. *Journal of Intelligent & Fuzzy Systems*, 29(2), 469-477. doi: 10.3233/IFS-141178

Turkan, Y., Bosché, F., Haas, C. T., & Haas, R. (2013). Toward automated earned value tracking using 3D Imaging Tools. *Journal of Construction Engineering & Management*, 139(4), 423-433. doi: 10.1061/(ASCE)CO.1943-7862.0000629

von Wangenheim, C. G., Savi, R., & Borgatto, A. F. (2012). DELIVER! – An educational game for teaching Earned Value Management in computing courses. *Information and Software Technology*, 54(3), 286-298. doi: 10.1016/j.infsof.2011.10.005

Willems, L. L., & Vanhoucke, M. (2015). Classification of articles and journals on project control and earned value management. *International Journal of Project Management*, 33(7), 1610-1634. doi: 10.1016/j.ijproman.2015.06.003