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Determination of Task Temporal Variations in Construction Scheduling Using Imprecise Probability

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CONSTRUCTION SCHEDULING

- In construction project management, scheduling and monitoring is crucial in successful and timely completion of project.
- Scheduling is performed through objective evaluations of each task involved in both spatial (physical correlation) and temporal (sequential correlation) domains.
- Temporal aspect of each task is defined by its expected duration, intended start time, and intended completion time.
- This duration is function of numerous factors including logistics, finance, and environmental conditions.
- Because of those project circumstances, duration of each task may experience variations and uncertainties.

EXAMPLE OF DELAYED CONSTRUCTION SCHEDULES

- United States South Carolina Department of Transportation (US SC DOT)
- Timeframe: February 2007 – August 2015
- Projects with construction schedules provided by contractors: 2097
- Projects delayed: 479
- Project still delayed after change order: 161

UNCERTAINTIES IN CONSTRUCTION SCHEDULING

- In order to guarantee that overall project completion time is not significantly exceeded, these uncertainties must be addressed so the allowable temporal variation for each task can be quantified.
- However, deterministic schemes are not capable of quantification of those uncertainties.
- Moreover, the traditional probabilistic approaches require a significant level of available data to correctly obtain the probability distribution function for each task.
- As the available data is limited, these approaches may result in errors when estimating those variations.

CURRENT METHODS FOR CONSTRUCTION SCHEDULING

The Critical Path Method (CPM)

- Utilized for planning and monitoring of both industrial and construction projects.
- Determines the overall duration of a project.
- Identifies, as well, the project's critical tasks whose temporal variations may increase and affect the overall project duration.
- Analysis performed in conventional CPM is deterministic.
- Does not consider the uncertainties in the activities' durations.

CURRENT METHODS FOR CONSTRUCTION SCHEDULING (Cont.)

Program Evaluation and Review Technique (PERT)

- Considers the presence of uncertainty in using probability theories.
- Task durations are described in terms of three values, the minimum, expected and maximum durations (used to define mean and standard deviation for each task).
- Requires a significant level of accuracy in the selection of the Probability Density Function (PDF).
- Assumes, mostly, a Beta distribution for each activity which may exhibit complexities regarding the notion of skewness.

ALTERNATE APPROACH – IMPRECISE PROBABILITY

- An alternative to having sufficient data to construct the “correct’ distribution is to estimate a range of distributions that represent possible activity duration.
- imprecise probability theory can handle uncertainty in a system with no assumptions of a well-defined PDF.
- Imprecise probability theory addresses the extraction of useful information about a process in the case that the PDF of system inputs or parameters may not be known.

RESEARCH OBJECTIVE

To develop a more robust methodology for construction planning and scheduling with uncertainties quantified through imprecise probability concepts.

METHODOLOGY

I. Define duration for each task using imprecise probability structures.

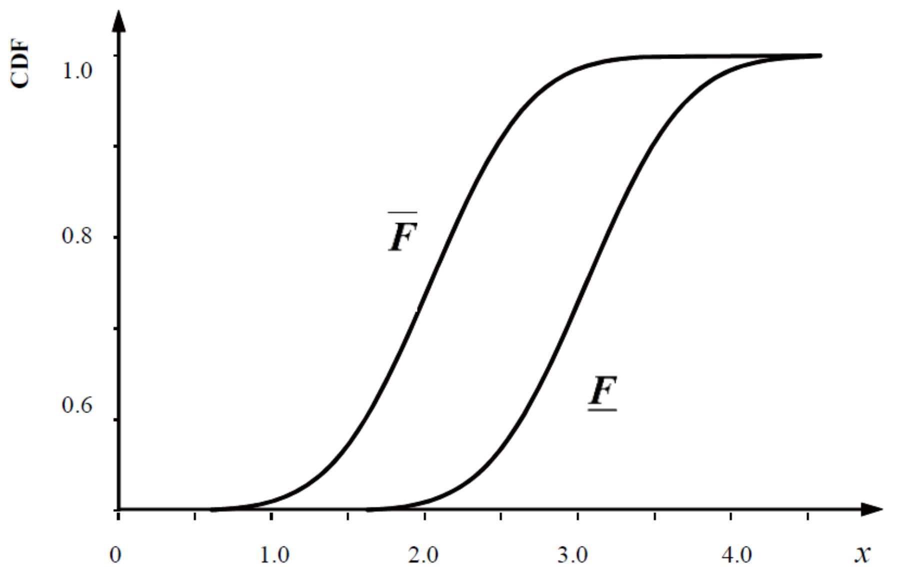
II. Construct the probability box (P-box) for duration of each task.

III. Use P-box arithmetic techniques for calculations between tasks throughout temporal evolutions during the overall project.

IV. Determine the bounds on the total project duration by consideration of uncertain duration for all tasks.

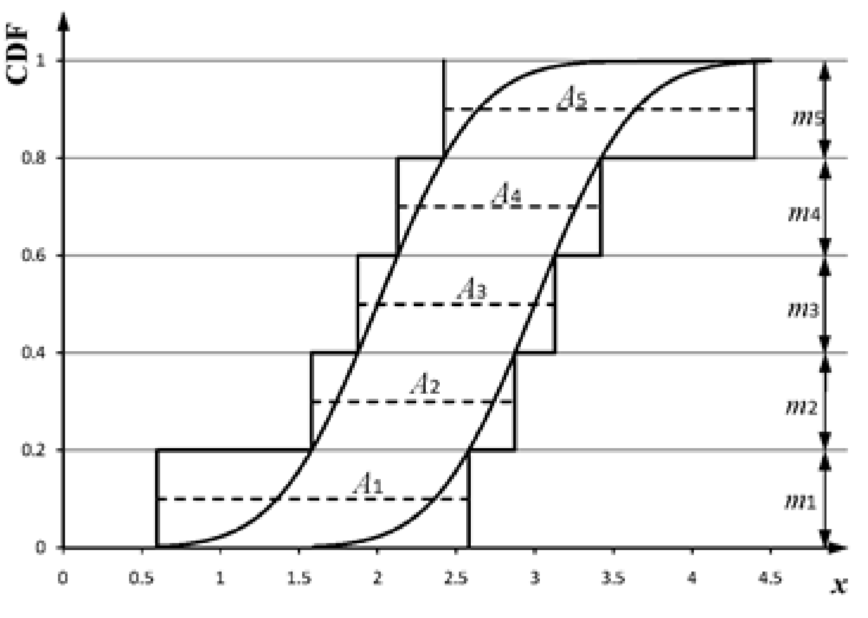
IMPRECISE PROBABILITY

- Framework for handling incomplete information with uncertain PDF or CDF
- Involves setting bounds on CDF based on deterministic or non-deterministic parameters (mean, variance, etc.)



Discrete Bounded P-Boxes

- A discrete P-box structure consists of a collection of interval values, each of which has an associated probability.
- In a uniform discretization, the associated probability for each interval is the same.



COMBINATION IN IMPRECISE PROBABILITY STRUCTURES

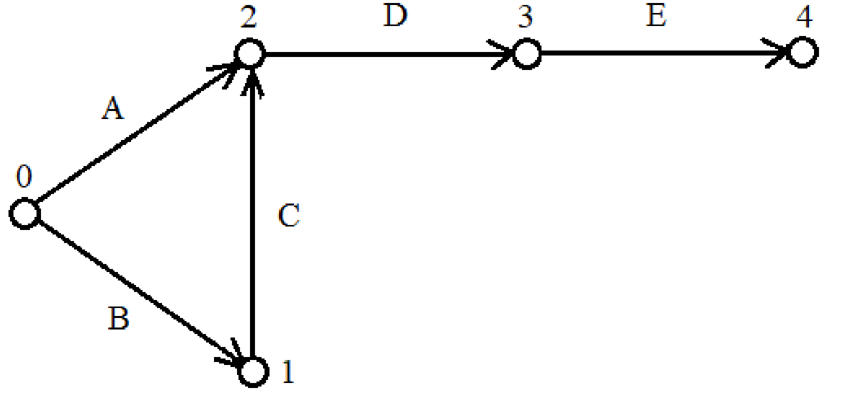
- Dempster-Shafer Structures
- Dependency Bounds Convolutions (Williamson and Downs 1990)
- Probability Bounds Analysis (Ferson and Donald 1998)
- Many methods expanded by Ferson et al. 2003, including: Enveloping
- This method uses enveloping for combining p-boxes

NUMERICAL EXAMPLE

Simple Network for Building Construction

Activity	Description	Start Node	End Node	Min Duration	Expected Duration	Max Duration
A	Order/prefab metal building	0	2	20	22	25
B	Clear site weather	0	1	5	10	15
C	Underground and foundation	1	2	5	10	16
D	Erect prefab building	2	3	8	10	20
E	Finish interior	3	4	9	10	11

Graphic Illustration

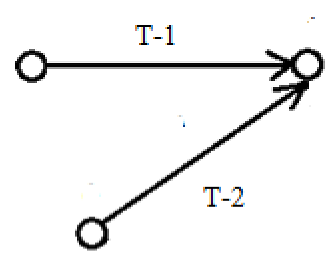


SOLUTION

- Probabilistic and Imprecise Probability approaches
- Expected duration for each activity considered stochastic
- Distribution: Truncated Independent Normal Distribution
- Mean= [(Min Time)+4*(Expected Time)+(Max Time)]/6
- Standard Deviation = [(Max time)-(Min time)]/6

SOLUTION (Cont.)

- For activities arrive at the same node, the P-box calculation is based of their union.



- Initiated at the starting node, The overall project calculations may require an iterative procedure.

ANALYTICAL RESULTS

Analytical Method	Overall Expected Project Duration (Days)
CPM	42
PERT Activity Time=(Min Time+4*Expected Time+Max Time)/6	43.5
Probability Approach The 95% confident limited	[43.20, 44.10]
Imprecise Probability (Independent-30 point discretization)	[43.02, 44.21]
Imprecise Probability (Independent-100 point discretization)	[43.37, 43.83]
Imprecise Probability (With any Dependencies)	[41.57, 47.49]
Interval Analysis (No assumption on distribution of activity duration, "worst-case interval")	[37,62]

OBSERVATIONS

- The results show that using an imprecise probability structure for event duration mean yields a series of more objective bounds for the overall duration than conventional CPM, PERT, and probabilistic approaches.

- Moreover, higher levels of discretization narrow the bounds more precisely.

- Furthermore, consideration of any dependencies yields wider results.

- Direct implementation of interval time durations with no assumption on the distribution yields the widest results compared to an imprecise probability approach.

CONCLUSIONS

- A new formulation for construction scheduling based on the concept of imprecise probability is introduced.
- This method can obtain the bounds for the mean of overall project duration with consideration of uncertainties in the values and distribution for duration of each activity.
- The results obtained from this method have a higher level of confidence and robustness due to objective evaluation of variations in the parameter distributions.
- This objectivity makes it attractive to introduce imprecise probability concepts in the field of construction scheduling and management.

QUESTIONS