# INTEGRATED SYSTEM FOR MANAGING OWNER-DIRECTED PROJECT ACCELERATION

**By Nagui I. Riad,[1] David Arditi,[2] Member, ASCE, and Jamshid Mohammadi,[3] Member, ASCE**

**ABSTRACT:** An integrated computerized system is described that can be used as a dispute-resolution tool for managing owner-directed acceleration. It can also be used as an aid for helping owners and contractors foresee the implications of accelerating a project in terms of cost and liabilities involved. The system is composed of an analysis module written in LISP as its backbone, and a knowledge base limited to related aspects in major contract forms. After obtaining the initial information from the user, the system triggers the analysis module. The analysis module generates several schedules to perform time-impact analysis. Then, the system uses the knowledge base to assign liabilities to the parties for past events, including delayed, accelerated, added, and canceled (DAAC) activities that were not foreseen in the original schedule. It does this by means of a set of if-then rules and certainty indices based on the responses obtained from the user. The system then incorporates this information chronologically into a compression analysis carried out again by the analysis module. The system can make a human mediator's job more effective and economical, and can also considerably reduce the occurrence of acceleration-related disputes.



## INTRODUCTION

The construction process has become increasingly a dispute-prone activity. The distribution of risks between the contractor and the owner is tilting in favor of the owner, leaving the contractor with enormous risks, including inflation, strikes, labor problems, adverse weather, accidents, shortages of materials and skilled labor, and unforeseen conditions at the construction site. The contracts binding the parties are becoming more complex. The adversarial relationship that has developed between the contractor and the owner over the years, coupled with the increasing complexity and magnitude of the projects, has increased the number and size of disputes.

The construction environment is sensitive to dispute. Whenever a dispute arises, the project suffers and progress slows down. Disputes divert resources from meeting project objectives, and consequently, project cost increases due to legal costs and the general disruption caused by the dispute. Construction firms, property developers, public agencies, and owners lose their reputation when disputes mark the headlines of trade magazines and newspapers.

At least four relatively unusual characteristics differentiate a construction dispute from other types of disputes: (1) Construction disputes usually involve more parties and more contracts than just the general contractor, the

[1]Former Grad. Student, Dept. of Civ. Engrg., Armour Coll. of Technol., Illinois Inst. of Technol., Chicago, IL 60616.

[2]Prof. of Civ. Engrg., Dept. of Civ. Engrg., Armour Coll. of Technol., Illinois Inst. of Technol., Chicago, IL.

[3]Prof. of Civ. Engrg., Dept. of Civ. Engrg., Armour Coll. of Technol., Illinois Inst. of Technol., Chicago, IL.

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owner and the agreement between the two; (2) the issues commonly raised are diverse, numerous, complex, and interwoven; (3) the events leading up to the dispute may take place over months, or even years; and, (4) the dispute often arises during, not after, construction, thereby requiring immediate decisions and actions during the heat of battle rather than affording the parties a reasonable period for reflection, study, review and consideration. The failure to act or react promptly may constitute a decision in itself, a decision that can yield disastrous long-term results (*Issues* 1988).

The legal requirement is to determine the time and cost for which each party involved in a claim is liable to the other. Owner-directed acceleration is the counterpart of owner-caused delay and also constitutes the subject of many claims. Contrary to how delays occur, acceleration is typically well thought out by the owner before the contractor is ordered to implement it. Generally, the purpose is to reach a certain milestone, possibly the completion of the project, before a certain deadline. Which activities have to be accelerated and what the terms of payment to the contractor will be are the subjects of many disputes.

Among the several dispute resolution methods, mediation has been an effective solution in dealing with disputes because it uses an experienced, impartial, and knowledgeable person in the construction process. However, all existing dispute resolution methods such as mediation, arbitration, litigation, and dispute review boards, have their drawbacks. Given the magnitude of the problem, there are distinct advantages for developing a computerized system that would be able: (1) To perform complex schedule analyses in a speedy, accurate, reliable, and economical way, using a high-level computer language; (2) to infer parties' contractual liabilities in delayed, accelerated, added, and canceled activities in the completed portion of a project, using expert-system technology; and (3) to apportion owner-directed acceleration costs between the parties, in the remaining portion of the project, based on a procedure that uses information acquired in items 1 and 2, and that is equitable to both the owner and the contractor. This type of integrated system could be used to simulate or manage planned acceleration at any given time during the life of a project.

MODA, an acronym for "managing owner-directed acceleration," is an integrated computerized system that can be used as a management tool that performs compression analysis in a cost-effective way, as a forecasting tool that highlights the implications of accelerating a project in terms of cost and liabilities involved, and as a dispute prevention and resolution tool that may reduce legal expenses in the long run (Riad 1990). The system can make a human mediator's job more effective and economical. It can also reduce the occurrence of acceleration-related disputes considerably because it is available to all parties at all times. For example, the owner who is planning to accelerate the remaining portion of the project will be able to observe the expected consequences (in terms of the parties' responsibilities with respect to time and money) by running the planned action through the system before the change is initiated. Similarly, the contractor will know ahead of time whether the acceleration ordered by the owner is wholly or partly his responsibility. This will help the parties reach an agreement before the decision for acceleration is made by the owner.

The objective of this paper is to describe MODA and to explain how it evaluates the impact of project acceleration on parties' liabilities. First the concept of acceleration is and its consequences are introduced. Existing methods of resolving the resulting disputes are reviewed. Then, the structure of MODA is described: the modules that respectively perform time-impact analysis, identify parties' liabilities, and finally apportion acceleration related costs are discussed.

## ACCELERATION

Acceleration of the work occurs when the contractor takes action to speed his progress in excess of the original schedule. This may involve adding to the work force, rental of extra equipment, overtime work, night operations or other steps designed to increase the pace.

When the contractor falls behind the established project schedule, and the reasons are not excusable, he is responsible for taking whatever steps are reasonably necessary to catch up. Of course, the expense he incurs in doing so is not recoverable.

If the owner desires to have the work, or some aspect of it, finished ahead of schedule, he is generally entitled to order the contractor to accelerate the pace of construction. In this situation, the owner issues and signs a formal change order requiring the acceleration, and the contractor receives additional compensation according to the change order procedures established by the contract.

Disputes arise, however, when the owner refuses a request for a time extension, or the owner implies in his communications with the contractor that the contractor must accelerate the pace of construction to avoid imposition of actual or liquidated damages. The contractor, rather than relying on his entitlement to a time extension and subsequently seeking to obtain funds withheld by the owner for the ensuing delay, may interpret the owner's action as requiring an acceleration in order to complete the work according to the original schedule. In this event, he may assert a claim for "constructive acceleration" against the owner, seeking to recover all costs, both direct and indirect, that the contractor has incurred. In order for the contractor to recover his costs from the owner under claim of "constructive acceleration," the following elements must exist (*Issues* 1988).

- There must be a period of excusable delay
- The owner must be given notice of the delay, unless the pertinent information is already known to the owner
- The contractor must submit a timely report for a time extension, in compliance with the contract requirements
- The contractor must give the owner a reasonable opportunity to grant or deny the request
- The owner must indicate that he will insist on completion by the originally scheduled completion date
- The contractor must actually accelerate the activities in the remaining portion of the project in an effort to meet the unextended date, which results in additional costs

The critical path method (CPM) is a tool that can help evaluate the cumulative effect of delays on total project duration. By referring to the provisions of the contract, it should be possible to establish the liabilities of the parties involved and to decide if an extension of the contract duration is warranted. The critical path method is a tool that can also help evaluate the effect of owner-directed acceleration. If acceleration is ordered in one specific activity, then its effect on the total project duration and the extra



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cost involved can easily be calculated. However, if acceleration is ordered in a project that was delayed by owner and/or contractor-caused events, then the apportioning of extra acceleration costs between the parties is not as simple. The various alternatives that are available for resolving this problem were reviewed and a procedure was developed by Arditi and Patel (1989) to reach a fair and reasonable solution. This procedure includes a mechanism called "time impact analysis." Time impact analysis is a procedure that involves the use of network-based scheduling tools to identify, quantify, and explain the cause of a schedule variance (Lee 1983), and it needs five types of network schedules:

1. The as-planned schedule: This is the original work schedule prepared by the contractor at the inception of the work. It reflects the contractor's planned approach to pursue the work.
2. The as-built schedule: It presents the actual sequence of events which occurred during the life of the project up to a given point in time. The as-built schedule contains all the delayed, accelerated, added, and canceled activities (called from now on DAAC activities) that took place in the completed portion of the project.
3. The adjusted schedules: A series of adjusted schedules are prepared to explain the sequence of events which transform the as-planned schedule into the as-built schedule, thus explaining the major schedule variances which occurred during the life of the project.
4. The as-projected schedule: Once all the work changes and delays are considered and an as-built schedule is generated for a given point in time, the expected project completion date has to be calculated. If the project is complete, the project completion date is the one shown on the as-built schedule. If the project is not complete, the as-built schedule has to be combined with the remaining activities of the project in the as-planned schedule in order to get an as-projected schedule which will show the expected project completion date.
5. The contractor/owner-accountable schedules: The responsibility for each DAAC activity that occurred in the completed portion of the project is assigned by using the contract documents, the chronological delay information collected during the course of the project, and accepted industry practices as a guide. Therefore, the contractor-accountable schedule will contain all the DAAC activities that were caused by the contractor. Similarly, the owner-accountable schedule will contain all the DAAC activities that were caused by the owner.

Data required for time impact analysis, i.e., activity durations and logical relationships, can easily be obtained from any project management package used by the parties. Retrieving information regarding the liabilities of the parties in each and every one of the DAAC activities that occurred in the completed portion of a project is not as simple, since some of the claims may not have been settled at the time of analysis. A method that infers the likely outcomes of such undecided claims is proposed later in this paper. Once this information is obtained, future acceleration costs are apportioned in Arditi and Patel's (1989) approach, in the same chronological order as the occurrence of past DAAC activities, as determined in time impact analysis.





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## DESCRIPTION OF MODA

MODA was developed using an expert-system shell called Personal Consultant Plus (Arditi and Riad 1988). Personal Consultant Plus is an integrated environment that offers the ability to extend and customize the consultation environment, and a built-in LISP interpreter (Texas Instruments Incorporated 1988).

Fig. 1 is an iconic representation of MODA. MODA contains two parts: the first part is an analysis module written in LISP that reads the input files imported from a scheduling software package, performs critical path analysis, identifies the DAAC activities, performs compression analysis, and apportions acceleration costs. The second part is the knowledge base that contains information regarding contractual conventions and procedural practices in the construction industry. MODA is the shell that controls the consultation. It is the interface between the analysis module, the knowledge base, and the user. It directs the question-answer session with the user; it calls the analysis module to perform, time, delay, and compression analyses; it triggers LISP procedures that calculate uncertainty indices, put DAAC activities in chronological order, apportion acceleration costs, and create final reports; and it uses the information in the knowledge base to assign liabilities in DAAC activities.

The structure of MODA consists of five frames, as shown in Fig. 2. The root frame, "claims," is at the top of the hierarchy followed by the revolve frame and three frames as children of the "revolve" frame, namely, "delayed," "accelerated," and "added/canceled." Children frames have access to the variables that are in their parent frames, yet the parents do not have access to their children's variables and the children do not have access to each other's variables.

The claims frame is responsible for managing and supervising the consultation as a whole, prompting the user for the initial information, initiating the LISP program if needed, and creating the final reports.

The revolve frame is responsible for reading in chronological order each and every DAAC activity that directly affects total project duration, and directing the path of the consultation to a child frame according to the type of the activity (delayed, accelerated, or added/canceled).

The delayed, the accelerated, and the added/canceled frames are responsible for

- Identifying the stage at which a claim is at the time of consultation
- Helping the user identify the liable party(ies) for an activity, through a question-answer session
- Assigning liabilities according to the user's answers
- Executing a LISP procedure that assigns a system confidence in the liability obtained in the previous step according to the stage at which the claim is, and the user's confidence in his answers
- Executing another LISP procedure that inserts the liable party(ies) in a list with their accompanying liability percentages and the confidence factors obtained in the previous step

The knowledge embedded in the expert system is acquired from major standard contracting forms including AIA Document 201A, EJCDC Standard Form, and GSA Form 23A. The information is strictly limited to aspects related to delay and acceleration. The standard conditions regarding

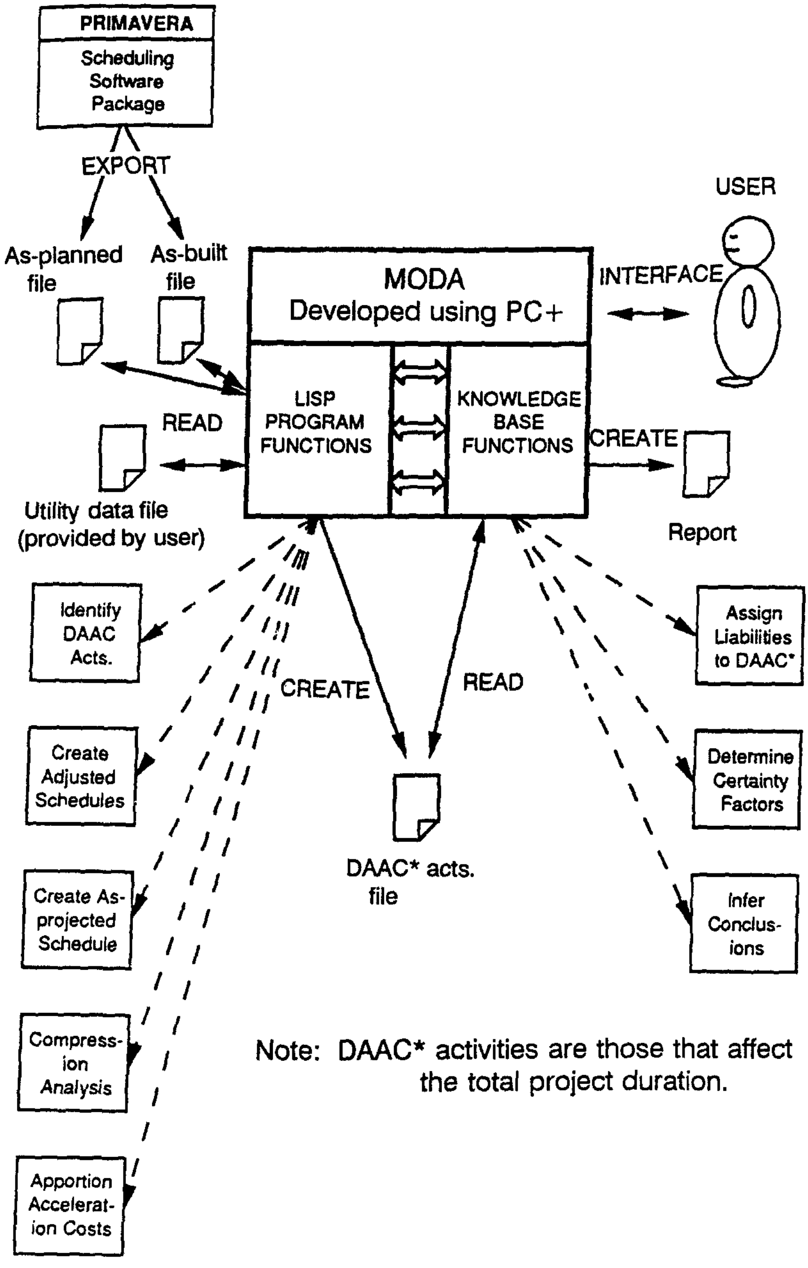


**FIG. 1. Iconic Representation of MODA**

delay and acceleration are fairly simple and straightforward. The rule base is consequently fairly simple and contains few rules. For example, according to the EJCDC Standard Form, "the making and acceptance of final payment shall constitute a waiver of all claims by Owner against Contractor . . . ,

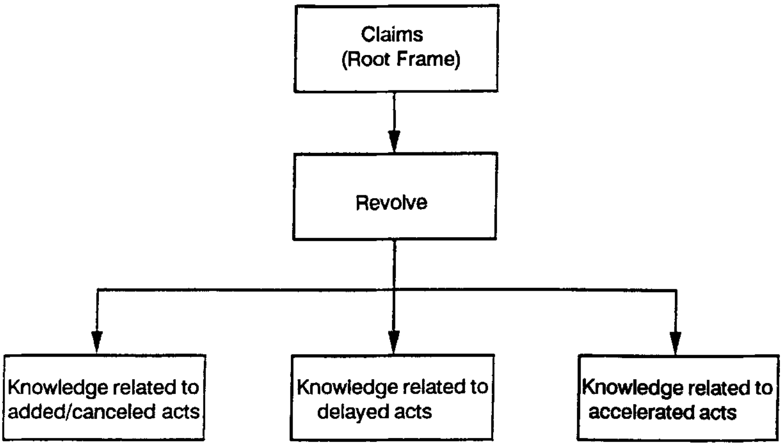


**FIG. 2. Structure of MODA**

and a waiver of all claims by Contractor against Owner other than those previously made in writing and still unsettled."

The structure of MODA is designed in a modular format that allows for future expansion, and ease of maintenance. The knowledge base can be expanded at any time in a way that does not affect the inferencing process.

The consultation starts by asking the user to input general information: user name, company name, type of contract, size of project, name of as-planned and as-built files that are imported from a project management package, and name of utility data file. The as-planned file contains activity descriptions, activity logic information, and estimated activity durations. The as-built file contains the actual start dates of activities in progress and actual start and finish dates of completed activities. The utility data file contains unit costs of activity compression expressed in dollars per day ($/day), number of days by which each activity can be compressed, and activity description. The user is also asked to specify the date on which the analysis is performed (this corresponds to the end date of the as-built schedule) and the number of days by which the user wants to accelerate the remaining portion. The data files and the input information for an example run are presented later.

The system-user interface is relatively user-friendly even though Personal Consultant Plus has a standard user interface that cannot be customized. All questions are presented to the user in the top left corner of the screen with all the choices underneath. However, a help feature allows the user to access various information. For example, when MODA asks the user to specify the name of the as-planned data file, the user may access the list of all such files in the computer's memory by simply pressing a help function key. Similarly, when the system asks the user to specify the type of contract between the contractor and the owner, the user can press a help function key to reach a screen with detailed information regarding each type of contract listed as alternatives under the question. If the user is curious about why certain questions are being asked, Personal Consultant Plus has a function that allows the user to trigger a "why" function, which will trace the rule linked to the particular question and explain to the user which rule the system is trying to prove.

## Time-Impact Analysis

Once the initial information is input by the user, MODA calls the analysis module. The analysis module runs a CPM analysis using the information in the as-planned file to get the planned early and late start dates of all activities. It then analyzes the accumulated information, compares the planned dates with the actual dates, and identifies the activities that have been delayed, accelerated, added, or canceled (DAAC activities). It stores the DAAC activities in chronological order by actual start date. Canceled activities do not appear in the as-built schedule and are therefore sorted by their planned early start date.

The analysis module creates the as-projected schedule by using the as-built activities with their actual start and finish dates in the completed portion of the project, and the as-planned activities in the remaining portion of the project that did not start yet. Activities in progress are treated as if they did not start yet and are located in the remaining as-planned portion of the network. A CPM analysis is then performed on this newly formed network to determine the combined effect of all DAAC activities on the total duration of the project.

The analysis module then creates the adjusted schedules. The adjusted schedules reflect the effect of each DAAC activity on the total duration of the project. The first DAAC activity in the chronological list is inserted into the as-planned schedule to generate the first adjusted schedule; the second DAAC activity in the chronological list is inserted into the first adjusted schedule to generate the second adjusted schedule; and so on until the last DAAC activity is inserted into the previous adjusted schedule to generate the last adjusted schedule. Once the adjusted schedules are created, the program identifies the DAAC activities that had an effect on the total project duration, marks them as DAAC*, and stores them in chronological order. The apportioning of acceleration costs will be performed by MODA at a later stage in the same chronological order, in accordance with the methodology developed by Arditi and Patel (1989).

## Identifying Liable Parties in DAAC* Activities

Once DAAC* activities are ordered chronologically, MODA next identifies the liable parties in each one of them. The system will use this information at a later stage of the consultation to apportion the cost of acceleration between the owner and the contractor. MODA assigns liability to past claims in DAAC* activities that have not yet been settled by using several decision parameters, including: (1) The stage of progress at which the claim is; (2) the decision regarding the claim made by the architect/engineer/contracting officer, if any has been made; (3) the type of DAAC* activity considered; (4) the user's opinion of the possible outcome of the claim; and finally (5) the user's level of confidence in his or her answers to the queries by the expert system.

The revolve frame in MODA picks the first DAAC* activity from the chronological list generated by the analysis module and presents it to the user, with all the information related to it, namely, its sequence number, its type (delayed, accelerated, added, or canceled), and its duration. It then asks the user if an agreement was reached regarding the liable party(ies) for this DAAC* activity. If there was a decision made that had been agreeable to the parties, the system asks the user to specify the decision. If no decision has been reached yet, the system internally branches, according to the activity's type, to one of the three frames that constitute the structure of the knowledge base (Fig. 2): it either branches to a frame that contains the rules related to added/canceled activities, to the frame for accelerated activities, or to the frame that contains the knowlege related to delayed activities.

In the frame that contains knowledge related to added/canceled activities, the expert system identifies through a set of if-then rules if the contractor was responsible for the addition or cancellation of that activity. Added/canceled activities are the responsibility of the owner in most cases.

Similarly, the system identifies if the contractor accelerated an activity to make up for his own past delays or if he was following the owner's orders. If an activity is accelerated on the owner's orders, the expert system decides if the owner is fully responsible for it by referring to the if-then rules located in the frame that contains accelerated activity information.

Finally, in the frame that contains delayed activity information, the system asks the user if a claim was filed for this DAAC* activity by the contractor to the architect, the engineer, or to the contracting officer, as the case may be in different types of contracts (AIA, GSA form 23A, or EJCDC). If a claim was filed, MODA asks the user to identify the stage of progress at which the claim process is, at the time of the consultation. The user is asked to choose from the alternatives presented to him by the system. These stages are

1. Notice or request: If a claim is in its early stages (for example, the contractor just submitted a notice to the architect), MODA tries to obtain a rough estimate from the user as to the extent to which each party is liable for the extra costs incurred in the activity. This will be based solely on the user's professional experience and intuition.
2. Rejection or compromise: In the stages where some primary action has been taken, MODA asks for that primary decision. Examples of primary decisions are that the contractor has filed a claim but the architect rejected it, or suggested a compromise; the contractor is not satisfied with the architect's decision and will probably seek mediation, arbitration, or litigation.
3. Mediation or Arbitration or Litigation: In the event that the parties agree to seek mediation, arbitration, or litigation, there are three stages of progress for each. These are briefly expained in Table 1.

Regardless of the stage at which the claim is, the user is asked to forecast the likely outcome of the claim. MODA also includes a standard question at the end of the consultation, for each DAAC* activity. It asks the user to specify separately for each DAAC* activity, the level of his confidence

**TABLE 1. Phases of Progress in Dispute Resolution Process**

| Phases of progress (1) | Dispute Resolution Methods | | |
|---|---|---|---|
| | Mediation (2) | Arbitration (3) | Litigation (4) |
| Phase I | Mediator has been selected | Arbitrator(s) has(ve) been selected | Trial has recently started |
| Phase II | Several meetings were held | Several hearings were conducted | Witnesses are being cross-examined |
| Phase III | Final decision is in the making | Final decision is in the making | Final decision is in the making |

in the opinion he expressed regarding the liable party(ies). The way the confidence information is treated is explained in detail in the next section.

When consultation ends for a paricular DAAC* activity, the revolve frame picks the next DAAC* activity in the chronological list and proceeds in the same way as just described, until all DAAC* activities are exhausted. An interface procedure adds the result of each consultation to a liability list. This information is then accessible to the analysis module for apportioning acceleration costs.

### Apportioning Acceleration Costs

Compression analysis is performed by the analysis module on the remaining portion of the project. Compression continues until either the network cannot be compressed anymore or the network has been compressed by a number of days that is equal to the number of days the user needs to accelerate the project. MODA then identifies the liable party(ies) for acceleration costs in compressed activities.

The knowledge embedded in the expert system regarding the apportioning of acceleration costs between the parties, is obtained from the methodology developed by Arditi and Patel (1989). The method is based on the premise that acceleration of the remaining portion of a project is typically ordered to compensate for the delays that occurred in the completed portion of the project and that acceleration conducted in the most economical way should follow accountability lines chronologically defined in previous delay impact analysis. In other words, the first and most economical compression should be the responsibility of the party who caused the first delay of equal magnitude, the second and more costly compression should be the responsibility of the party who caused the second delay of equal magnitude, and so on. Acceleration costs are therefore apportioned in the chronological order as DAAC* activities occurred in the completed part of the project.

The interface between the analysis module and the knowledge base is achieved by several procedures written in LISP. An interface procedure creates a report in ASCII format that contains all the information related to the DAAC* and compressed activities, each accompanied by its unit compression cost, the amount that each party is responsible for, and finally, the expert system's confidence in the decisions made. The user can retrieve this file for his records. Reports generated in an example run are presented later.

## TREATING UNCERTAINTIES ASSOCIATED WITH USERS' INPUTS AND EXPERTS' KNOWLEDGE

Expert systems make use of the heuristic type of knowledge that is usually retained by experts. They are also expected to interpret and accommodate inputs from users who are often not sure of their answers to the systems' queries. When designing an expert system, the uncertainties associated with such heuristic expert knowledge as well as hesitant user input have to be treated in such a way that the system's credibility and reasonableness can be improved.

There are several ways to deal with uncertainty in expert systems. Diekmann and Kraiem (1990) summarize three common methods used for uncertain reasoning in expert systems: (1) The probabilistic method (Allwood 1989; Adams 1984); (2) fuzzy-set theory (Gupta 1977); and (3) the confirmation (certainty factors) method. The selection of one method over the



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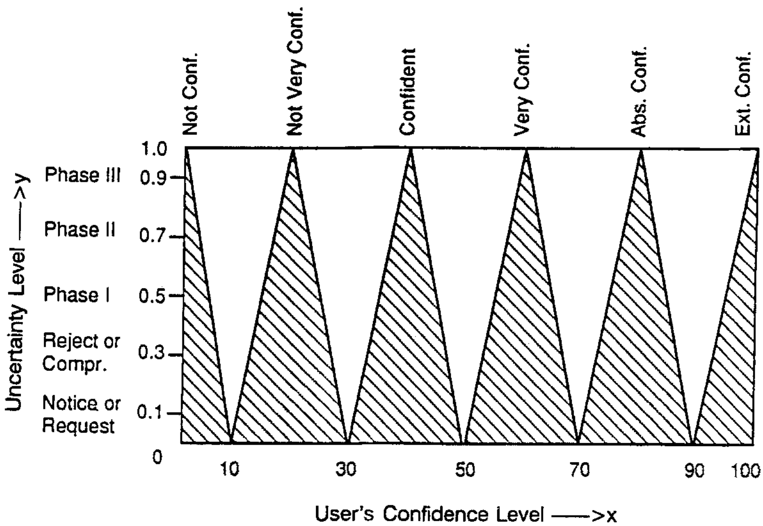


Phases I, II or III refer to phases in mediation, arbitration or litigation, respectively.

**FIG. 3. Translational Model**

others depends on the function and objective of the expert system being designed. The probabilistic and the confirmation methods can be used if adequate data to support reasonable estimates of the probability measures and certainty factors are available.

The model that was used in developing MODA is a triangular translational model (Fig. 3) that is similar to models used in fuzzy-set analysis. This two-dimensional model translates linguistic input obtained from the user into numerical confidence values. The linguistic input is obtained as a response to the expert system's query regarding the likely decision that is to be reached in a particular claim, concerning the liabilities of the parties. The user is also asked to specify the stage of progress in the claim as well as the confidence level in the input. MODA generates a numerical value for each DAAC* activity by using these inputs within the context of the model presented in Fig. 3. These numerical values represent the confidence of MODA's decision in individual DAAC* activities. These values are then averaged at the end of the consultation and the total confidence in the apportioned acceleration costs is presented to the user.

The model's $y$-axis represents the uncertainty associated with the stage of progress in the claim and covers the range 0.1 to 0.9 with 0.2 increments. For example, opinions expressed in early stages of the claim process such as the contractor just having turned in his or her notice or request, are assigned less credibility (0.1) than opinions expressed in later stages, such as towards the end of the arbitration process (phase III: 0.9). The values assigned to each stage were selected by the writers in the absence of any specific information in the literature.

The $x$-axis of the model presented in Fig. 3, represents the user's confidence in the answers regarding the liability he assigned to a DAAC* activity. It ranges from 0 to 100, where 0 represents no confidence, and 100 means that the user is absolutely confident about his answers.



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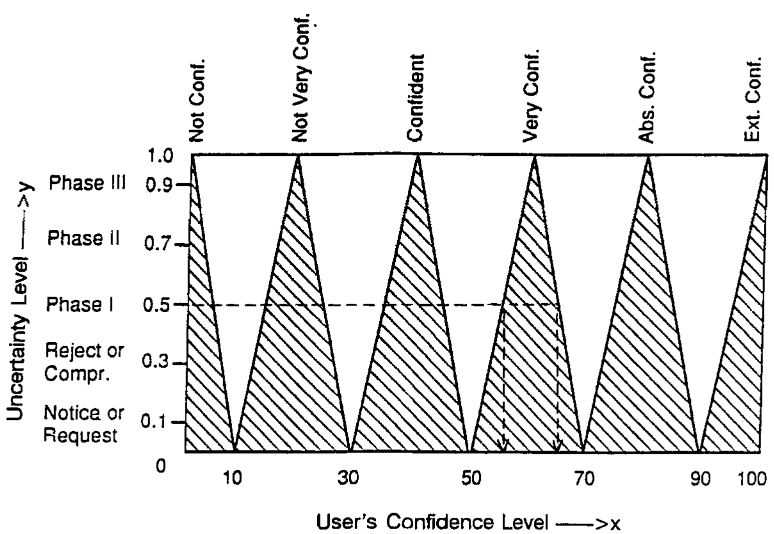
The shaded triangles in Fig. 3 indicate that the confidence level expressed by the user is subject to more dispersion at the bottom of the chart, i.e., in the early stages of a claim. The dispersion decreases toward the apex of the shaded triangles, where the claim process has reached a more advanced stage.

The uncertainties associated with the user's response and the impact of the stage of progress at which the claim process is, are then combined to arrive at a single "certainty index" for each DAAC* activity. One of the methods that can be used to calculate such an index is based on selecting a specific value on the translation lines for each linguistic response. For example, if the user is "very confident" about his response while the claim is at phase I of arbitration, it can be observed from Fig. 4 that the certainty index for the outcome should lie between 55% and 65%. A conservative design would use the lower bound confidence value (55% in this case), whereas a risk-averse design would use the higher bound value (65% in this case) consistently.

Another method that can be used is based on manipulating the areas separated by the translation lines (Hadipriono 1989). This method is more global in the sense that it does not have the extreme conservative or risk-averse characteristics mentioned in the first method. That is why it has been selected for use in MODA. The certainty index ($I$) in this method is obtained using the following equation:

$$I_i = A_l - A_r + C \qquad (1)$$

where $I_i$ = certainty index for the $i$th DAAC* activity; $A_l$ = area to the left of the triangle that represents the user's confidence and below the stage of progress in the claim; $A_r$ = area to the right of the triangle that represents the user's confidence and below the stage of progress in the claim; and $C$ = a constant representing the area of the universe of discourse (=100).




Phases I, II or III refer to phases in mediation, arbitration or litigation, respectively.

**FIG. 4. Certainty Indices by Lower-Bound Method**

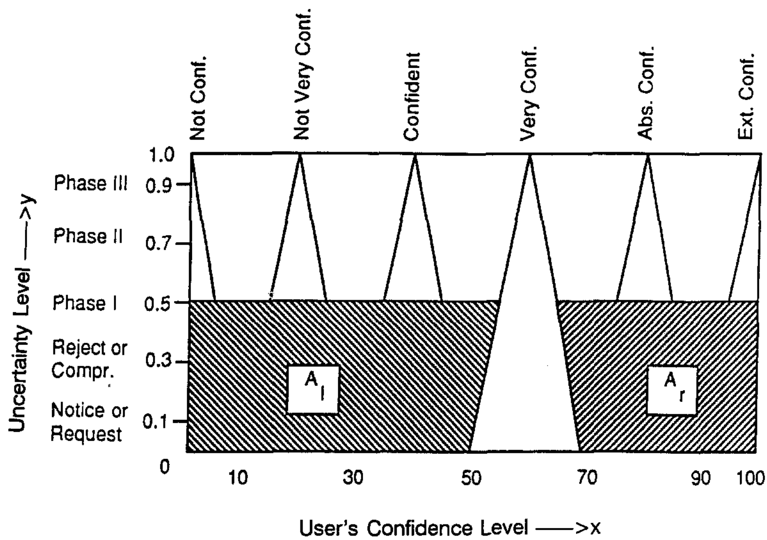



**FIG. 5. Certainty Indices by Area Calculation**

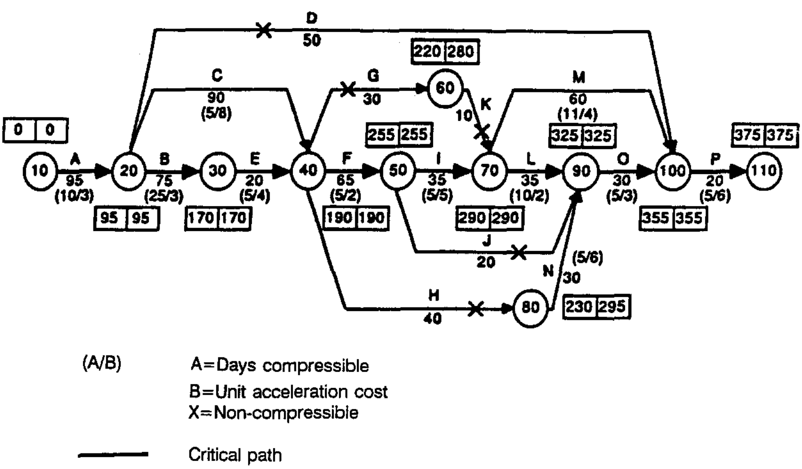



**FIG. 6. As-Planned Schedule for Example Run**

Fig. 5 shows an example for the case where the arbitration process is in "Phase I," and the user's confidence in his response is categorized by the user as "very confident."

After obtaining certainty indices ($I_i$) that represent the system confidence in the liability assigned to the party(ies) in each DAAC* activity, the system calculates a weighted average for the entire process according to

$$I = \frac{\sum_{i=1}^{n} (N_i \cdot I_i)}{\sum_{i=1}^{n} N_i} \qquad (2)$$



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| Preceding Node Number | Succeeding Node Number | Original Duration | Activity Description |
|---|---|---|---|
| 10 | 20 | 95 | A |
| 20 | 30 | 75 | B |
| 20 | 40 | 90 | C |
| 20 | 100 | 50 | D |
| 30 | 40 | 20 | E |
| 40 | 50 | 65 | F |
| 40 | 60 | 30 | G |
| 40 | 80 | 40 | H |
| 50 | 70 | 35 | I |
| 50 | 90 | 20 | J |
| 60 | 70 | 10 | K |
| 70 | 90 | 35 | L |
| 70 | 100 | 60 | M |
| 80 | 90 | 30 | N |
| 90 | 100 | 30 | O |
| 100 | 110 | 20 | P |

**FIG. 7. As-Planned Data File**

where $I$ = total confidence in apportioning acceleration costs (%); $N_i$ = number of days by which the $i$th DAAC* activity affected the total project duration; $I_i$ = confidence index for the $i$th DAAC* activity; and $n$ = number of DAAC* activities.

## EXAMPLE RUN

The example consists of a fictitious project whose as-planned schedule is presented in Fig. 6. The input files used and the reports generated are as follows.

The owner of the construction has signed a fixed-price contract with XYZ contractor for the "AlphaOne" project. The value of the contract is $7,000,000 and the contract documents follow the AIA Document A201.

On the 315th day of the project the owner realizes that the project cannot be completed in 375 days as originally scheduled in the as-planned schedule because of a series of delayed, canceled, and added activities. Activity R is a new activity that has a duration of 174 days and that is located between existing nodes 10 and 30. It consists of extra work that was not anticipated in the time the contract was signed. On the other hand, activity C has been canceled. There have been delays in two activities, namely activities B and E of 4 and 21 days, respectively. Time-impact analysis indicates that, as a



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| Preceding Node Number | Succeeding Node Number | Actual Start Time | Actual Finish Time | Activity Description |
|---|---|---|---|---|
| 10 | 20 | 1 | 95 | A |
| 10 | 30 | 1 | 174 | R |
| 20 | 30 | 96 | 174 | B |
| 20 | 40 | 96 | 95 | C |
| 20 | 100 | 96 | | D |
| 30 | 40 | 175 | 215 | E |
| 40 | 50 | 216 | 280 | F |
| 40 | 60 | 216 | 245 | G |
| 40 | 80 | 216 | 255 | H |
| 50 | 70 | 281 | 315 | I |
| 50 | 90 | 280 | | J |
| 60 | 70 | 256 | 265 | K |
| 70 | 90 | 316 | | L |
| 70 | 100 | 316 | | M |
| 80 | 90 | 260 | | N |
| 90 | 100 | | | O |
| 100 | 110 | | | P |

**FIG. 8. As-Built Data File**

result of these changes the project is expected to finish on day 400, with a total project delay of 25 days. Because the owner is expected to deliver the rental portion of the project on original schedule, he or she decides to explore the possibilities of accelerating the remaining portion of the project by 25 days and the cost involved in doing so.

Because a popular project-management software package is used on this project, the owner exports the as-planned (ASP.PRN) and the as-built (ASB.PRN) files, in ASCII format, from the original project data (Figs. 7 and 8). The utility data file (COMPRESS.PRN) is created in an editor (Fig. 9).

The input used in the example run consists of the following.

- User name: Nagui Riad
- Company name: Illinois Institute of Technology
- Total dollar amount of the contract: $7,000,000
- Project name: AlphaOne
- As-planned file name: ASP.PRN
- As-built data file name: ASB.PRN
- Utility data file name: COMPRESS.PRN
- User type: Owner





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| Unit Acceleration Cost ($/unit of work period) | Compressible duration (unit of work period) | Activity Description |
|---|---|---|
| 3,000 | 10 | A |
| 3,000 | 25 | B |
| 8,000 | 5 | C |
| 0 | 0 | D |
| 4,000 | 5 | E |
| 2,000 | 5 | F |
| 0 | 0 | G |
| 0 | 0 | H |
| 5,000 | 5 | I |
| 0 | 0 | J |
| 0 | 0 | K |
| 2,000 | 10 | L |
| 4,000 | 11 | M |
| 6,000 | 5 | N |
| 3,000 | 5 | O |
| 6,000 | 5 | P |

**FIG. 9. Utility Data File**

- Contract Description: AIA Document A201
- Type of contract: Fixed-price
- Unit of work period: Day
- Final payment: Not made yet
- Day analysis performed: At the 315th day of the project
- Accelerate project by: 25 days

After submitting the three files to MODA, the consultation starts. The three files are analyzed, liabilities assigned, and finally the owner is informed that the project can be accelerated by 20 days only because compression data for the remaining portion of the project does not allow further reduction in project duration. The reports generated by MODA are presented in Fig. 10. The first part of the generated reports lists the initial information supplied by the user at the beginning of the consultation. Next comes tabular information regarding DAAC and DAAC* activities, including description, duration, type of change, liable party, and user's confidence in his opinion. The compressed activities and their related information (description, days compressed, unit compression cost, and total compression cost) are tabu-

Project Name : AlphaOne

User Name : Nagui Riad

Company Name : Illinois Institute of Technology

User Status : Owner

Contract Description : AIA

Type of Contract : Fixed Price

Contract Value : $7,000,000

The following is a list of all DAAC activities:

| DAAC Activity Name | Duration (Days) | Type of Activity | Liable Party | C** |
|---|---|---|---|---|
| R* | 174 | NEW | OWNER | 90% |
| C | 90 | CANCELED | | |
| B | 4 | DELAYED | | |
| E* | 21 | DELAYED | OWNER | 42% |

* Activities for which liability has been evaluated are those that affect total project duration (DAAC* activities)
** C denotes the confidence level in %

The network portion after the day of analysis is compressed as follows:

| Compressed Activity Name | DAYS Compressed | Cost/Unit ($/day) | Compression Cost |
|---|---|---|---|
| L | 5 | 2,000 | 10,000 |
| P | 5 | 6,000 | 30,000 |
| M and L | 5 | 6,000 | 30,000 |
| M and O | 5 | 7,000 | 35,000 |

TOTAL ESTIMATED COMPRESSION COST = $105,000

The owner will be responsible for : $105,000

The contractor will be responsible for : $0

Nagui Riad,

As you might have realized by now, the process of assigning liabilities is a highly subjective process and therefore the results may be uncertain.

The following percentage reflects the confidence of the system in the apportioning of acceleration costs between the owner and the contractor: 48%.

**FIG. 10. Reports Generated by MODA**



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lated next. Finally, the report presents the acceleration costs for which each party is responsible and the system's confidence in the results.

## CONCLUSION

The number and magnitude of recent lawsuits as well as the risk-averse attitude of the parties in the construction business are indicative of the seriousness of the situation concerning contract disputes. The cost of litigation and the damage to reputations have become so pronounced in the last few years that parties in the construction industry have been trying to minimize disputes and resolve disagreements through fast, economical, convenient, efficient, and amicable processes. One such computerized process is presented in this paper for managing owner-directed acceleration.

MODA is a system that generates the necessary interim schedules given the original planned data and the actual achieved dates in completed activities. Time-impact analysis is performed on these schedules (as-planned, as-built, as-projected, adjusted) automatically, responsibility is apportioned for past delayed, accelerated, added, and canceled (DAAC) activities, a compression analysis is performed on the remaining portion of the project, and acceleration costs are apportioned by using a fair and equitable method. All this is achieved by means of a computerized system that integrates expert system technology and conventional programming in LISP.

The contractor who uses MODA at any time during the course of the project should be able to calculate the amount of liquidated damages the contractor will face if the project is completed at a later date than the date originally specified in the contract. The contractor may then choose to accelerate the remaining portion of the project in order to minimize liquidated damages or may try to prevent further delays in the remaining portion of the project, hence containing the damage to what has already been incurred.

Similarly, the owner of the construction should be able to run MODA to establish how the contractor has been performing in the completed portion of the project. The owner could also identify DAAC activities that were the owner's or the designer's own doing. If the analysis indicates that a large portion of the overall expected delay is the owner's fault, then the owner will have to review his business practices including his designer's and consultants' performance in order to minimize the reoccurrence of similar cases in the remaining portion of the project. MODA will help reduce the number of disputes caused by acceleration decisions, hence reducing the enormous cost of resolving such disagreements.

The prototype of MODA is operational and has been extensively tested. An example run was presented. The analysis module, written in LISP, is accurate and reliable within the context of the application presented in this paper. The knowledge base contains basic information found in major standard contract forms but limited to delays and accelerations. The performance of the expert system could be improved if it relied less on users' uncertain opinions and more on facts and legal considerations. For example, MODA asks the user's opinion as to what the outcome of a past claim should be, if a decision agreeable to both parties has not been reached yet. It then treats this opinion with a certainty index that it calculates based on the user's confidence in his response, and the stage of progress in the claim. MODA's performance could be improved if satellite programs were developed that could treat in greater depth different types of claim, such as errors in design, overinspection, strikes, contractor performance, problems with material delivery. These satellite programs could be appended to MODA as they became available while the approach used in the present prototype could be confined to assign liabilities in the remaining claims. An expert system that was developed using Personal Consultant Plus and that could be immediately incorporated into MODA is a program called DISCON, which deals with changed site conditions (Cobb and Diekmann 1986).

Future research could also be directed to enhancing the handling of uncertainty in user input. For example, the translational model used in MODA could be improved by conducting an independent survey of claim managers that could allow the developers to translate linguistic inputs related to user confidence into numerical values more accurately. Similarly, the final confidence in MODA's final decision that is presented in percentage value in the prototype version, could also be translated into linguistic mode to make it more meaningful for the user.

MODA is an integrated computerized system that can be used by owners, contractors, expert witnesses, courts of law, mediators, arbitrators, and dispute resolution boards to facilitate dispute resolution. It can also be used by owners and contractors before any dispute arises, to simulate the consequences of planned acceleration. It is not designed to replace human decision but rather to force the parties not to rush into acceleration decisions without having thoroughly explored the consequences. If a dispute arises, MODA can help the parties reach more informed resolutions.

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