DECISION MODEL FOR THE SELECTION OF THE ARMY'S INDIVIDUAL SOLDIER WEAPON SYSTEM

MGMT 224
Executive Decision Making
Professor Forman

Michael Rithmire
Vasya Gorshkov
Dave Cabrinha

February 7, 1998

DECISION MODEL FOR THE SELECTION OF THE ARMY'S INDIVIDUAL SOLDIER WEAPON SYSTEM

Abstract

The office of the Deputy for System Management at Army headquarters is evaluating candidate systems to fulfill the Army's need for an individual soldier weapon. The Army currently uses a Byzantine process, involving many players and no particular order to the process, for selecting weapon systems. We have attempted to conduct an independent system trade analysis for the Army's new individual soldier weapon system as an example of how this process could be conducted more efficiently using modern analytic techniques. The Army is considering developing a new missile system for use in Low Intensity Conflict, Special Operations, and Military Operations in Urban Terrain. The Army wants a system that will be capable of defeating lightly armored vehicles, earth and timber bunkers, reinforced concrete walls, and brick walls. The system should be light enough to be carried by one soldier and can be fired from within an enclosure such as a bunker or building. Also, the system should be designed using sufficiently mature technology so as to preclude an overly long and costly development program and should have a relatively low unit cost once in production.

Introduction

The decision model developed to evaluate the three candidate weapon systems is based on a number of objectives considered important in the design, production, use, and maintenance of the system. The problem is complex as there aren't any dominant solutions - each of the candidate systems has unique characteristics that make it preferable with respect to certain individual objectives. Additionally, the alternatives are mutually exclusive - the Army has only limited resources with which to design and procure the chosen system. To complicate the situation, some of the objectives are conflicting, making it necessary to make compromises. For this decision, we used the Analytical Hierarchy Process, which helped us to manage the complexity and weigh the competing objectives.

Alternatives

The candidate systems we have chosen are the Multi-Purpose Individual Munition (MPIM), the Javelin anti-tank missile, and the Bunker Defeat Munition (BDM). A brief description of each system follows.

MPIM

The MPIM is a shoulder-fired guided missile with a unique warhead designed specifically for defeating shelters and bunkers. The MPIM is capable of engaging targets at ranges up to and beyond 500 m. The warhead blasts an opening into brick or reinforced concrete walls and then propels an anti-personnel grenade into the room. The grenade is set to detonate in the center of the room and incapacitate the room's occupants. The MPIM is inertially guided, which significantly increases its effective range and enables it to engage moving vehicles.

Javelin

The Javelin is a shoulder-fired anti-tank missile designed to defeat heavily armored tanks at ranges up to and beyond 2 km. The Javelin is guided by an infrared sensor and does not require any input from the operator once the target is designated and the missile is launched. The Javelin warhead is optimized to defeat tank armor and does not contain an anti-personnel grenade. The Javelin warhead is capable, under limited conditions, of penetrating brick and concrete wall.

BDM

The BDM is a free flight (unguided) rocket that is optimized for defeating earth and timber bunkers. The warhead does not contain an anti-personnel grenade and the rocket cannot be fired from within enclosures; however, the BDM has a very low unit cost in comparison to Javelin and MPIM because of its extremely low technical complexity.

Pros and Cons of Alternatives

In evaluating each alternative, we attempted to list major pros and cons of each alternative in order to prepare ourselves for structuring a logical decision model. The pros and cons of each alternative are as follows:

MPIM

Pros:

- Warhead optimized for the stated mission objectives (defeats brick and concrete walls, and delivers anti-personnel grenade).
- Can be fired from within enclosures.
- Can engage moving targets.
- Minimum firing signature.

Cons:

- New, unique warhead design with inherent technical risk.
- Relatively complex to manufacture.
- Costly components.

Javelin

Pros:

- Fire-and-forget, affording maximum soldier survivability.
- Engages targets at long ranges.
- Already in production - proven technology and manufacturing technique.
- Can be fired from within enclosures.
- Can engage moving targets.

Cons:

- Not designed for this mission.
- Expensive unit cost.
- Does not carry anti-personnel grenade.

BDM

Pros:

- Inexpensive due to low technical complexity.
- Capable of defeating walls and bunkers.
- Already in production - proven technology.

Cons:

- Unguided rocket - requires operator to be close to target.
- Cannot be fired from within an enclosure.
- Does not carry anti-personnel grenade.

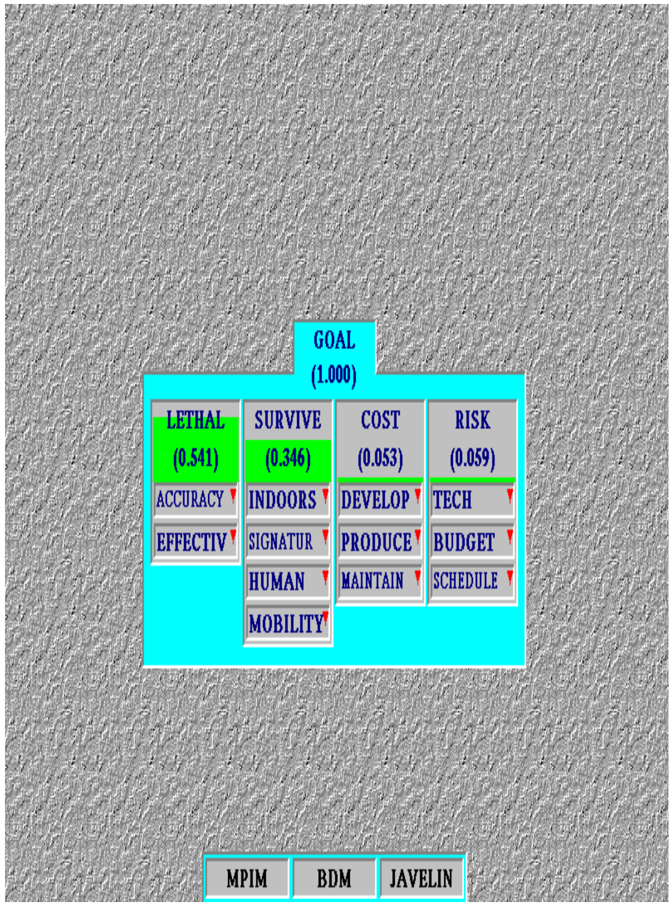
Structuring a Decision Model

We have determined that the following primary objectives were the most relevant for our decision as to which weapon system to choose. The Expert Choice model's top-level objectives are shown in Figure 1. The sub-objectives are shown in Figure 2.

- Lethality: relative lethal capability against the desired target set.
- Survivability: capability to increase the soldier's effectiveness against enemy fire and prevent enemy detection when launched.
- Cost: relative measure of development, production, and maintenance costs.
- Risk: various risks associated with designing, developing, and procuring the system.

Figure 1 - Decision Objectives Heirarchy

Select Individual Soldier Weapon



Abbreviation	Definition
ACCURACY	Accuracy for selected target set
BUDGET	Risk of developing and producing the weapon within budget

Educational Use Only

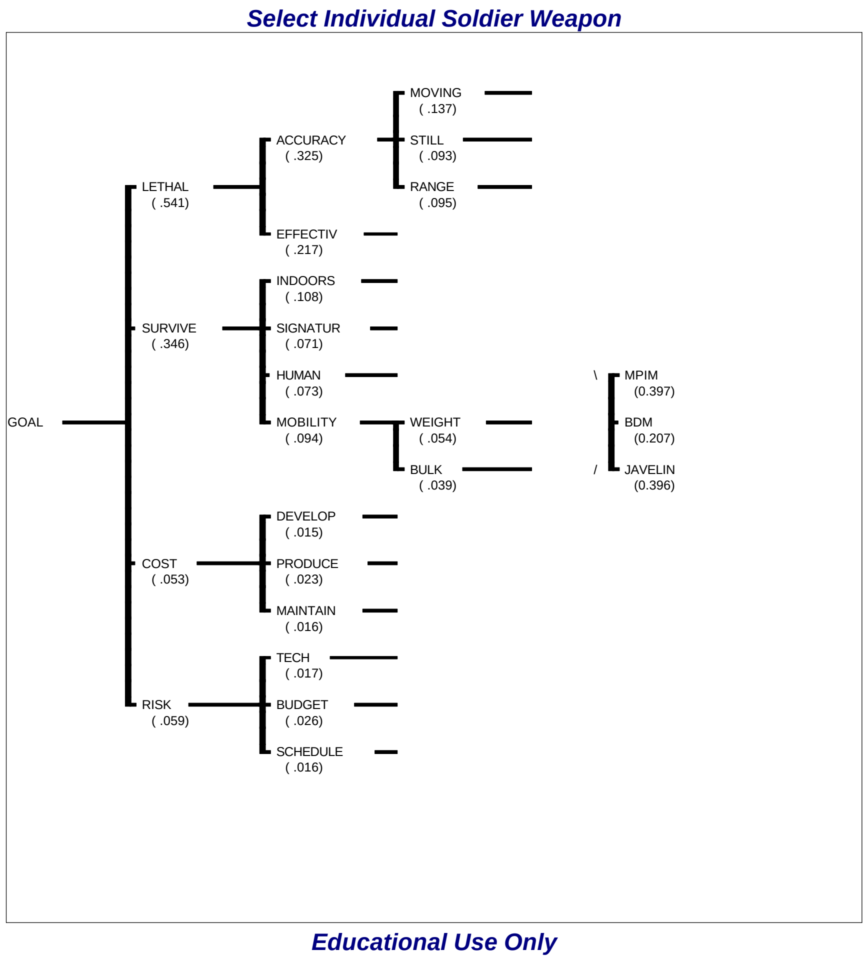


Figure 2. EC Sub-Objectives and Associated Priorities

Select Individual Soldier Weapon

Synthesis of Leaf Nodes with respect to GOAL

Ideal Mode

Abbreviation	Definition
GOAL	
ACCURACY	Accuracy for selected target set
BDM	Bunker Defeat Munition
BUDGET	Risk of developing and producing the weapon within budget
BULK	Bulk of the weapon
COST	Low Unit Prodution Cost
DEVELOP	Non-Recurring cost to develop the weapon
EFFECTIV	Effectiveness against selected target set
HUMAN	Human Factors - the ease of setting up and firing the weapon
INDOORS	Ability to fire the weapon indoors
JAVELIN	Javelin Antitank Missile
LETHAL	Lethal Capability Against Bunkers & Light Armor
MAINTAIN	Cost to maintain the weapon's effectiveness over time
MOBILITY	Affects of the weapon on soldiers' movements
MOVING	Accuracy for moving targets
MPIM	Inertial Guided Individual Munition
PRODUCE	Recurring cost to produce the weapon in desired quantities
RANGE	Effective range of the weapon
RISK	Risk in developing/fielding the weapon
SCHEDULE	Risk of developing and producing the weapon on schedule
SIGNATUR	Launch signature of the weapon (flash, smoke, and noise)
STILL	Accuracy for stationary targets
SURVIVE	Increase Soldier Survivability
TECH	Risk in developing/producing the technology req'd for the weapon
WEIGHT	Weight of the weapon

Educational Use Only

Figure 2a. Definitions

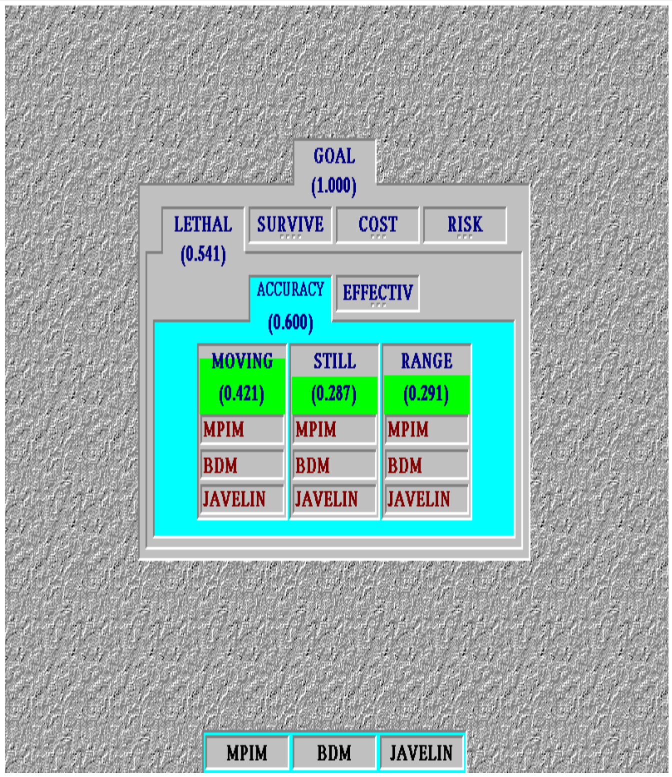
Lethality is the most important objective in our model. Lethality, in this case, relates to a given system's ability to defeat the target defined for this mission. When the Army makes plans to develop a new weapon system, the decision is initiated by a document known as a Mission Need Statement. The Mission Need Statement specifies the specific operational scenario that the weapon system will be used in and the types of targets that will most likely be engaged. For this particular scenario, urban (guerilla) warfare, the targets are brick and concrete walls and lightly armored vehicles such as personnel carriers. When developers design a missile, the warhead is optimized for the required target and the hope is it will also be effective against other targets as well. Therefore, we have determined that the lethality objective (against brick and concrete walls) as being high. The weapons being considered in this analysis are believed to be the closest fit for this target set whereas other missiles would have very low lethality ratings because they aren't designed for this particular target set.

Our lethality objective is broken down further into two sub-objectives: accuracy and effectiveness. Accuracy is basically a measure of how well the missile will fly to the intended target and is further broken down into accuracy against moving targets, accuracy against stationary targets, and range (see Figure 3). In the case of Javelin or MPIM, both are self-guided and will fly, using an autopilot, to the operator-designated target. BDM, on the other hand, has no guidance mechanism and will simply fly in the direction it is fired, leaving the effects of wind, gravity, and other disturbances to divert it from its intended course. Thus, Javelin and MPIM will rank high when compared to

BDM from an accuracy standpoint. Effectiveness describes the relative damage each system's warhead can impart on the required targets, given that the missile actually impacts.

Figure 3. Lethality Sub-Objectives

Select Individual Soldier Weapon

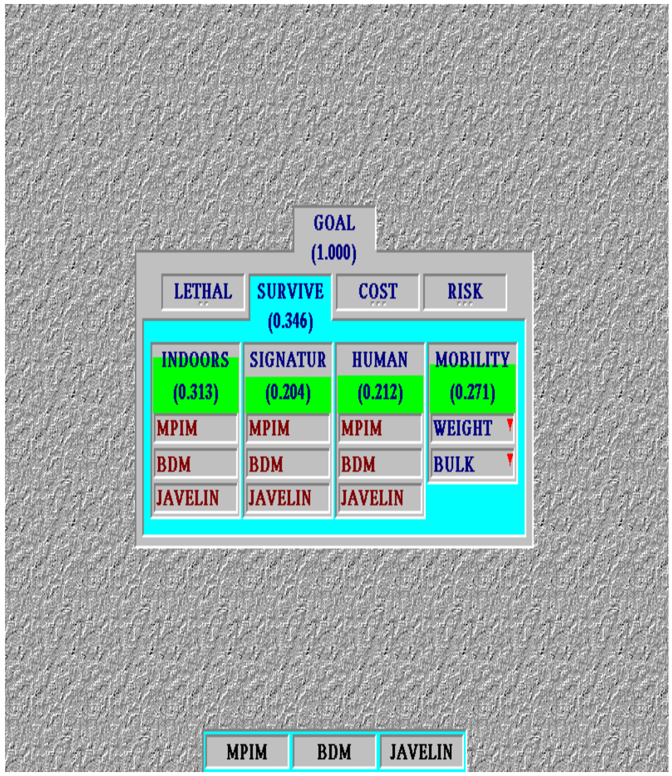


Abbreviation	Definition
ACCURACY	Accuracy for selected target set
BDM	Bunker Defeat Munition

Educational Use Only

Our second objective, in order of importance, is survivability (see Figure 4). In this case, survivability means the operator's chance of survival during a battle while using the system. Survivability is divided into four sub-objectives: the ability to fire the weapon indoors, the launch signature, ease of use (human factors), and mobility. Indoors is defined as the ability to fire the missile from inside an enclosure such as a room or bunker. This allows the operator to fire at the enemy without exposing himself to hostile fire. Signature is the visual effect (flash and smoke) which is produced when a candidate system is fired. Ease of use is a measure of all the human factor issues affecting the operator. Finally, mobility is defined as factors that affect the soldier's ability to be mobile while carrying the weapon. Mobility is further subdivided into bulk (physical bulkiness of the system) and weight.

Select Individual Soldier Weapon



Abbreviation	Definition
BDM	Bunker Defeat Munition
BULK	Bulk of the weapon

Educational Use Only

Figure 4. Survivability Sub-Objectives

The final two objectives, rated nearly equally in importance, are cost and risk. Cost is further subdivided into development (non-recurring cost to develop the system), production (recurring cost to mass-produce), and maintenance (costs associated with life cycle support of the system after it is fielded) sub-objectives. This objective addresses the risk of technical barriers during the development (technical sub-objective), cost growth (cost sub-objective), and schedule slips (schedule sub-objective).

Weighting of Objectives

Using a graphical pairwise comparison of the four objectives, we derived weights for survivability, lethality, cost, and risk, as well as the associated sub-objectives. As previously discussed, the lethality objective is the most important. Using the pairwise comparison methodology, we determined that the lethality objective is approximately ten times more important than both the risk and cost objectives. Survivability is approximately six times more important than cost and risk. Lethality was determined to be 1.5 times more important than survivability. These comparisons resulted in the following priorities for the objectives:

- Lethality – 0.541
- Survivability – 0.346
- Risk – 0.059
- Cost – 0.053

Figure 2 indicates the priorities afforded the sub-objectives. In each case, the differences between the different sub-objectives were relatively slight. Although the differences in priority are important, we didn't feel that any of the sub-objectives were instrumental in determination of the final recommendation.

Evaluation of Alternatives

The alternatives we selected were evaluated against all of the sub-objectives and, consequently, against the four principal objectives. Each of our alternatives was assessed using pairwise comparisons for the first iteration of our analysis. Most of the comparisons can be made verbally based on a knowledge of the three alternatives. For example, the effectiveness of each candidate in meeting the lethality objective is measured by reviewing the outcome of test flights against the required targets. If the system imparted the requisite amount of damage then it will satisfy this objective. The Javelin can penetrate brick and concrete walls; however, the effect it has on personnel inside the structure is not fully known. Therefore, it was rated lower than MPIM in this category. BDM, on the other hand, doesn't even penetrate a brick wall of the required thickness so it is rated lower than both Javelin and MPIM. We rated MPIM highest in this category because of its unique warhead, which was designed specifically for this type of target.

MPIM and Javelin both rated high for meeting the objective to fire from inside an enclosure, a survivability sub-objective. MPIM and Javelin were also rated high for meeting the low signature requirements primarily because BDM must be fired outside of a protected area, increasing the likelihood of enemy detection. BDM rated highest in human factors because it simply requires a trigger pull to be activated. Javelin and MPIM both require the operator to designate the target prior to launch.

BDM is the lightest and least bulky of the three systems, winning it high marks for mobility. Javelin ranked lowest in this category because it weighs 49 pounds and the objective is for the system to weigh 20 pounds or less. MPIM is currently estimated to weigh exactly 20 pounds.

When we assessed the alternatives against the cost objective we found that Javelin was rated highest because it is already developed and in production. BDM was rated second because technical issues remain which will require further development to resolve. MPIM was rated lowest in this category because it is in the early stages of development and the funds to complete the effort have not yet been budgeted.

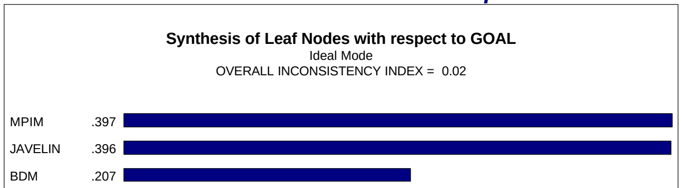
BDM rated best for the production cost sub-objective because of its relatively low unit price of approximately $5K. MPIM was in the middle with a unit cost of approximately $17K, and Javelin was lowest with a unit cost of approximately $75K. The three alternatives were rated the same for maintenance cost based on the relative complexities of the three systems.

Conclusion

Of the three alternatives considered, the MPIM and Javelin were prioritized very closely together following their evaluation against the objectives (see Figure 5). The BDM was clearly an inferior solution considering the objectives. A sensitivity analysis of the decision indicates that the risk objective appears to be the primary differentiating factor between the MPIM and the Javelin (see Figure 6). This is because both systems were ranked fairly closely with respect to each of the primary objectives with the exception of the risk objective. Figure 7 shows the performance sensitivity of the alternatives with respect to the goal. Since the decision is based mostly on the relative performance of the two systems with regard to the risk objective, it would be prudent to solicit other expert opinions to confirm that the two alternatives are, in fact, equally preferable with respect to the other objectives. It is also possible that the relative weights of the objectives are misstated.

The actual decision on which of these three candidates will be selected is made by the Army Acquisition Executive based upon the recommendation of many people including the Deputy for Systems Management. We presented our model and results to the chief of the Tactical Missiles branch (under the Deputy for Systems Management) and received favorable comments and interest. The chief of Tactical Missiles wanted to know more about Expert Choice and how it can be used in analyzing complex decisions such as choosing new weapon systems for development. He was also surprised to see how clearly each of the factors which play in this type of decision can be displayed and evaluated.

Select Individual Soldier Weapon



Abbreviation	Definition
MPIM	Inertial Guided Individual Munition
JAVELIN	Javelin Antitank Missile
BDM	Bunker Defeat Munition

Educational Use Only

Figure 5. Synthesis of Alternatives wrt to Goal

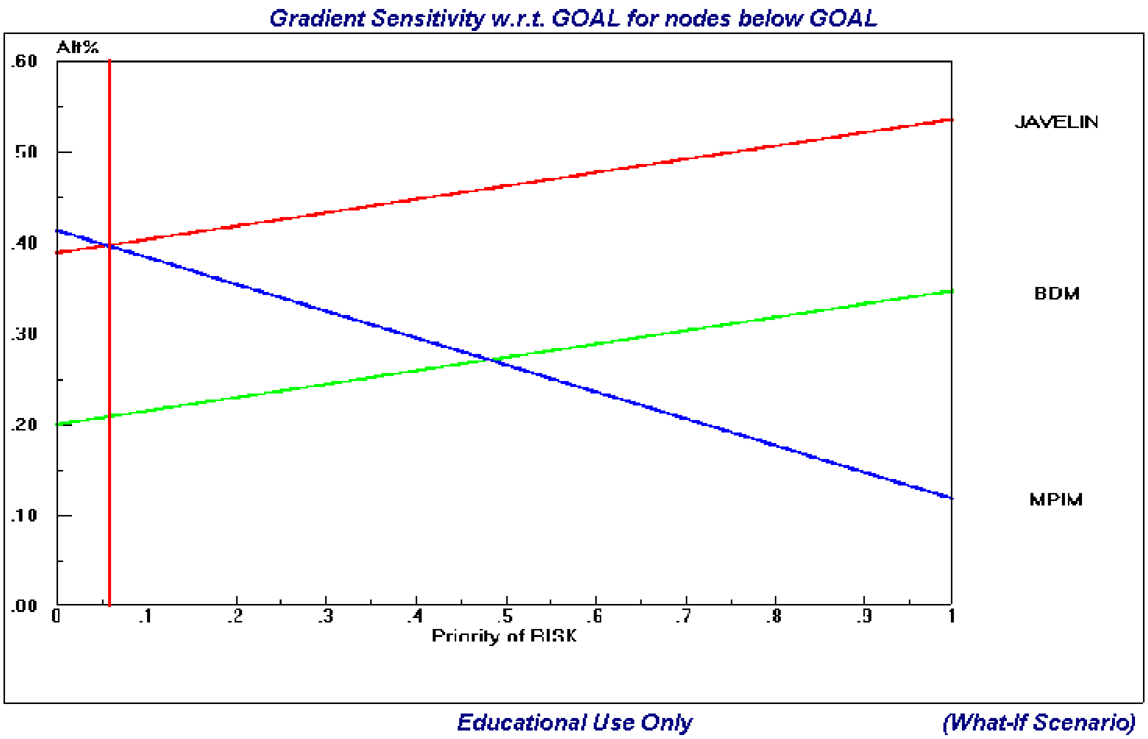


Figure 6. Sensitivity wrt Risk

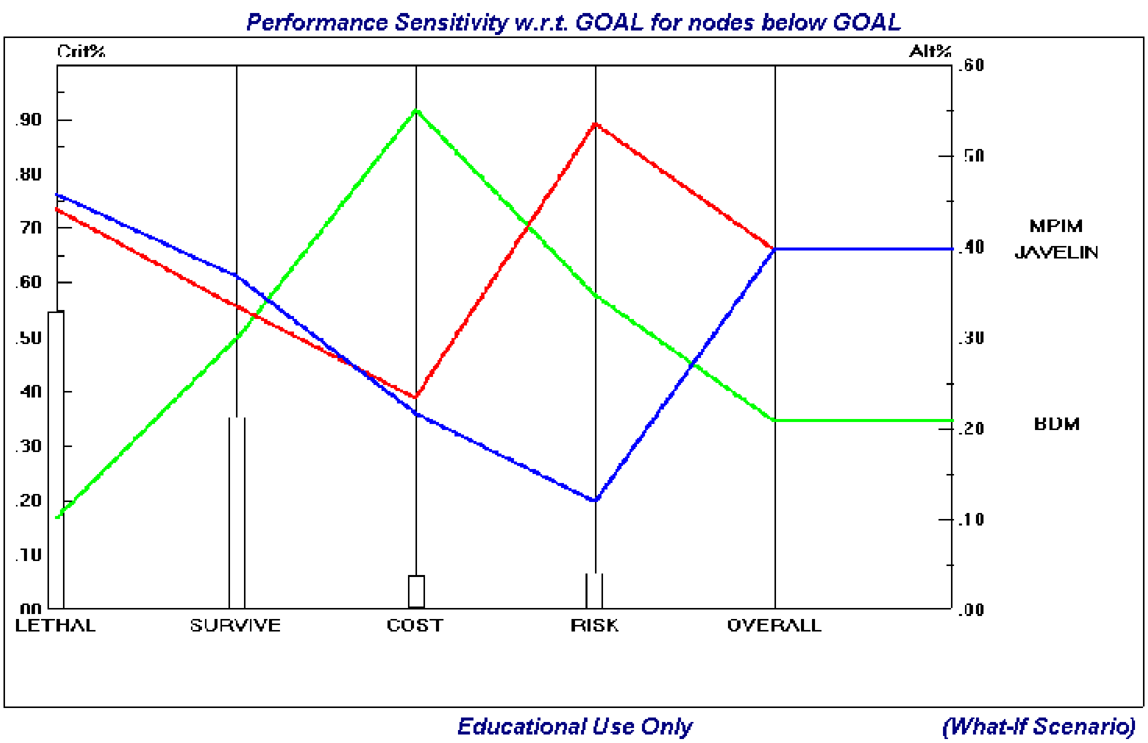


Figure 7. Performance Sensitivity of the Alternatives