Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

ΘΑΛΗΣ – Πανεπιστήμιο Πειραιά
Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια

Δ18 – Διοργάνωση workshops

Π18.4 – Έκθεση 4ου Επιστημονικού Workshop

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

Στοιχεία παραδοτέου

Δράση: Δ18 – Διοργάνωση workshops

Τίτλος παραδοτέου: Π18.4 – Έκθεση 4ου Επιστημονικού Workshop

Τύπος παραδοτέου: I - PP

Έκδοση: 01

Ημερομηνία: 28 Απριλίου 2014

Υπεύθυνος σύνταξης: Καθηγητής Ιωάννης Σίσκος

Ομάδας σύνταξης: Καθηγητής Διονύσης Γιαννακόπουλος
Καθηγητής Αθανάσιος Σπυριδάκος
Αναπληρωτής Καθηγητής Ευάγγελος Γρηγορούδης
Δρ. Νικόλαος Τσότσολας
Δρ. Ιώαννης Πολίτης
Νικόλαος Χριστοδουλάκης, MSc.
Γεωργία Μουριάδου, MSc.

Περιεχόμενα

<u>Συντομογραφίες Παραδοτέου</u>

ΣΕ: Συντονιστής Έργου

ΥΕΟ: Υπεύθυνος Ερευνητικής Ομάδας

ΚΕΟ: Κύρια Ερευνητική Ομάδα

ΟΕΣ: Ομάδα Εξωτερικών Συνεργατών

ΟΕ: Ομάδα Έργου

ΥΔΠΕ: Υπεύθυνος Διασφάλισης Ποιότητας Έργου

ΕΥΔ: Επιστημονικός Υπεύθυνος Δράσης

ΟΕΜ: Ομάδα Εμπειρογνωμόνων

ΠΑΠΕΙ ή UNIPI: Πανεπιστήμιο Πειραιά

ΠΚ ή TUC: Πολυτεχνείο Κρήτης

ΕΜΠ ή NTUA: Εθνικό Μετσόβιο Πολυτεχνείο

1 Γενικά

1.1 Γενικά στοιχεία δράσης

Η δράση Δ18 αφορά τη διοργάνωση μιας σειράς επιστημονικών συναντήσεων εργασίας (workshops) και εντάσσεται στο σύνολο των δράσεων δημοσιότητας του έργου. Τα workshops οργανώνονται από τις ερευνητικές ομάδες των ιδρυμάτων που συμμετέχουν στην υλοποίηση του έργου και είναι ανοικτά για το κοινό, δεδομένου ότι απευθύνονται σε ερευνητές, υποψήφιους διδάκτορες, μεταπτυχιακούς φοιτητές, κ.λπ. που εργάζονται ή σκοπεύουν να ασχοληθούν με το ευρύτερο αντικείμενο της πολυκριτήριας ανάλυσης.

Στα πλαίσια των επιστημονικών αυτών συναντήσεων παρουσιάζεται όχι μόνο η τρέχουσα έρευνα που έχει πραγματοποιηθεί στα πλαίσια του έργου και αφορά τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια, αλλά και το γενικότερο αντικείμενο της πολυκριτήριας ανάλυσης αποφάσεων.

Πιο συγκεκριμένα, οι στόχοι των επιστημονικών workshops είναι:

- η παρουσίαση των τρέχουσας ερευνητικής προσπάθειας που αφορά τη μελέτη της ευστάθειας στην πολυκριτήρια ανάλυση αποφάσεων,
- η παρουσίαση της γενικότερης θεωρίας και των πρακτικών εφαρμογών της πολυκριτήριας ανάλυσης αποφάσεων,
- η διάδοση του επιστημονικού αντικειμένου της πολυκριτηρίας ανάλυσης αποφάσεων και
- η δικτύωση και η ανταλλαγή απόψεων ανάμεσα σε επιχειρησιακούς ερευνητές και στελέχη επιχειρήσεων και οργανισμών που ασχολούνται με το συγκεκριμένο αντικείμενο.

Σύμφωνα με το πλάνο υλοποίησης, στα πλαίσια του συγκεκριμένου έργου πρόκειται να πραγματοποιηθούν 6 επιστημονικές συναντήσεις εργασίας (workshops), οι οποίες κατανέμονται σε 2 ανά έτος και 2 ανά ερευνητική ομάδα. Η γενική εποπτεία των συναντήσεων θα γίνεται από τη Μικτή Επιτροπή Συντονισμού του Έργου (βλ. δράση Δ21), στην οποία συμμετέχουν οι υπεύθυνοι των 3 ερευνητικών ομάδων. Πιο συγκεκριμένα, η Μικτή Επιτροπή Συντονισμού του Έργου αποτελείται από τους:

1. Καθηγητή Ιωάννη Σίσκο (συντονιστή έργου και υπεύθυνου της ερευνητικής ομάδας του ΠΑΠΕΙ)
2. Καθηγητή Κωνσταντίνο Ζοπουνίδη (υπεύθυνου της ερευνητικής ομάδας του ΠΚ)
3. Καθηγητή Ιωάννη Ψαρρά (υπεύθυνου της ερευνητικής ομάδας του ΕΜΠ)

Δεδομένου ότι η επιτροπή αυτή έχει ως στόχο τη συνολική παρακολούθηση υλοποίησης του έργου, η συνεισφορά της στη συγκεκριμένη δράση επικεντρώνεται στο συντονισμό με τις υπόλοιπες ενέργειες του έργου και τη συνεργασία με τον εκάστοτε διοργανωτή του επιστημονικού workshop.

1.2 Γενικά στοιχεία παραδοτέου

Το συγκεκριμένο παραδοτέο αφορά το 4ο Επιστημονικό Workshop του έργου που πραγματοποιήθηκε στον Πειραιά, το χρονικό διάστημα 2-3 Απριλίου 2014. Σύμφωνα με το χρονοδιάγραμμα υλοποίησης του έργου, τη χρονική στιγμή διεξαγωγής του workshop έχουν ολοκληρωθεί:

1. Οι βιβλιογραφικές δράσεις του ερευνητικού προγράμματος:
   - Δ1: Βιβλιογραφική ανασκόπηση ανάλυσης ευστάθειας σε αναλυτικές-συνθετικές διαδικασίες
   - Δ5: Βιβλιογραφική ανασκόπηση προσεγγίσεων τεχνικής νοημοσύνης για την ανάλυση ευστάθειας πολυκριτήριων προβλημάτων
   - Δ9: Βιβλιογραφική ανασκόπηση ανάλυσης ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού
2. Η ανάπτυξη μέτρων αξιολόγησης της ευστάθειας:
   - Δ2: Ανάπτυξη μέτρων αξιολόγησης ευστάθειας σε αναλυτικές-συνθετικές διαδικασίες
   - Δ6: Ανάπτυξη μέτρων αξιολόγησης ευστάθειας σε προβλήματα ταξινόμησης
   - Δ10: Ανάπτυξη μέτρων αξιολόγησης μέτρων ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού
3. Η πειραματική αξιολόγηση των μέτρων ευστάθειας:
   - Δ3: Πειραματική αξιολόγηση μέτρων ευστάθειας σε αναλυτικές-συνθετικές διαδικασίες
   - Δ7: Πειραματική αξιολόγηση προσεγγίσεων τεχνικής νοημοσύνης για την ανάλυση ευστάθειας πολυκριτήριων προβλημάτων
   - Δ11: Πειραματική αξιολόγηση μέτρων ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού
4. Οι εφαρμογές των μεθοδολογιών μέτρησης και βελτίωσης της ευστάθειας:
   - Δ4: Εφαρμογές ανάλυσης ευστάθειας σε αναλυτικές-συνθετικές διαδικασίες
   - Δ8: Εφαρμογές προσεγγίσεων τεχνικής νοημοσύνης για την ανάλυση ευστάθειας πολυκριτήριων προβλημάτων
   - Δ12: Εφαρμογές ανάλυσης ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού

Επιπλέον, οι ερευνητικές ομάδες που συμμετέχουν στο πρόγραμμα βρίσκονται στο στάδιο της ανάπτυξης του λογισμικού και της υπολογιστικής υλοποίησης των μέτρων ευστάθειας (δράσεις Δ13 και Δ14) με βάση τα αποτελέσματα των προηγούμενων δράσεων.

Στα πλαίσια του 4ου Επιστημονικού Workshop του έργου πραγματοποιήθηκε παρουσίαση των μέχρι σήμερα αποτελεσμάτων από όλες τις ομάδες που συμμετέχουν στο πρόγραμμα δίνοντας έμφαση στις δράσεις που έχουν ολοκληρωθεί έως τώρα αλλά και τις προδιαγραφές των συστημάτων υποστήριξης αποφάσεων που πρόκειται να αναπτυχθούν στα πλαίσια αυτού του έργου και βρίσκονται σε στάδιο υλοποίησης. Στο παραδοτέο αυτό δίνονται:

- Γενικές πληροφορίες για τη δράση (τόπος, χρόνος διεξαγωγής, συμμετέχοντες, κ.λπ.)
- Συνοδευτικό υλικό της δράσης (αφίσα, δελτίο τύπου, παρουσιάσεις, κ.λπ.)
- Άλλο πρόσθετο υλικό (φωτογραφίες, κ.λπ.)

Επίσης, θα πρέπει να σημειωθεί ότι στα πλαίσια της συγκεκριμένης δράσης δίνεται για άλλη μια φορά η δυνατότητα συνάντησης των μελών των ερευνητικών ομάδων, γεγονός που είναι ιδιαίτερα σημαντικό σε ένα έργο που έχει ως βασικό αντικείμενο τη συνεργασία ερευνητικών ομάδων. Επίσης, η συγκεκριμένη δράση έχει και έναν χαρακτήρα προβολής των αποτελεσμάτων του έργου σε επιστήμονες και φοιτητές που δραστηριοποιούνται στον χώρο της πολυκριτήριας ανάλυσης αποφάσεων.

2 Υλοποίηση

2.1 Γενικές πληροφορίες workshop

Το 4ο Επιστημονικό Workshop με διακριτικό τίτλο “Robust MCDA» (ακρωνύμιο του έργου) πραγματοποιήθηκε στις 2-3 Απριλίου 2014 στο ΤΕΙ Πειραιά. Το workshop διοργανώθηκε από την ερευνητική ομάδα του ΠΑΠΕΙ, στην οποία συμμετέχουν και ερευνητές από το Πολυτεχνείο Κρήτης, το ΤΕΙ Πειραιά, καθώς και ερευνητές της αλλοδαπής.

Για τις ανάγκες διοργάνωσης του workshop προετοιμάστηκε κατάλληλο ενημερωτικό υλικό (αφίσα, φυλλάδιο), το οποίο παρουσιάζεται στα Παραρτήματα Α-Β της παρούσας έκθεσης.

Όπως παρουσιάζεται αναλυτικά στην επόμενη παράγραφο, το workshop περιλαμβάνει 3 ενότητες:

1. Ανάλυση ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού, συμπεριλαμβανομένων των προβλημάτων ακέραιου γραμμικού προγραμματισμού.
2. Μέτρηση της ευστάθειας σε αναλυτικές-συνθετικές προσεγγίσεις, με έμφαση στα προβλήματα λήψης ομαδικών αποφάσεων.
3. Εναλλακτικές προσεγγίσεις αντιμετώπισης προβλημάτων ευστάθειας σε συλλογικά αναλυτικά-συνθετικά μοντέλα (μέθοδος MUSA).

2.2 Απολογισμός workshop

Στο workshop συμμετείχαν και οι 3 ερευνητικές ομάδες του έργου, καθώς και σημαντικός αριθμός νέων επιχειρησιακών ερευνητών. Πιο συγκεκριμένα, δόθηκε η δυνατότητα συμμετοχής στους μεταπτυχιακούς φοιτητές του ΠΜΣ «Επιστήμη των αποφάσεων με πληροφοριακά συστήματα» (ΦΕΚ 764/Β/3-4-2013) που διοργανώνει το ΤΕΙ Πειραιά, Τμήμα Διοίκησης Επιχειρήσεων, δεδομένης της συνάφειας που παρουσιάζει το πρόγραμμα σπουδών με το αντικείμενο του έργου.

Ο Πίνακας 2.1 παρουσιάζει τα μέλη της ΚΕΟ και της ΟΕΣ του έργου που συμμετείχαν στο 4ο Επιστημονικό Workshop. Το Workshop παρακολούθησαν επίσης μεταπτυχιακοί φοιτητές, υποψήφιοι διδάκτορες και ερευνητές του Πανεπιστημίου Πειραιά, του Εθνικού Μετσόβιου Πολυτεχνείου Κρήτης και του ΤΕΙ Πειραιά. Συνολικά, ο αριθμός των συμμετεχόντων ανήρθε σε 35 άτομα.

Συνοπτικά, το πρόγραμμα του 4ου Επιστημονικού Workshop έχει ως εξής:

Τετάρτη 2 Απριλίου 2014

09:30 – 10:00: Προσέλευση και καλωσόρισμα από τους Διοργανωτές Καθ. Δ. Γιαννακόπουλο, Καθ. Α. Σπυριδάκο και τον Συντονιστή του έργου Καθ. Ι. Σίσκο

10:00 – 11:30: Robustness in multi-objective project portfolio se-lection taking into account energy and environmental corporate responsibility and performance uncertainty – George Mavrotas, Haris Doukas, Olena Pechak, Panos Xidonas

11:30 – 12:00: Διάλειμμα

12:30 – 13:30: Measuring the robustness of Pareto sets in multi-objective integer programming problems – George Mavrotas, José Rui Figueira, Eleftherios Siskos

13:30 – 14:30: Διάλειμμα

14:30 – 16:00: Measuring robustness in aggregation-disaggregation approaches: The case of UTA methods – Nikos Tsotsolas, Athanasios Spyridakos, Denis Yannacopoulos, Nikos Christodoulakis

16:30 – 16:30: Διάλειμμα

16:30 – 18:00: Enriching interactivity of disaggregation-aggregation approaches through the exploitation of robustness analysis results - Athanasios Spyridakos, Yannis Siskos, Denis Yannacopoulos, Nikos Tsotsolas

Πέμπτη 3 Απριλίου 2014

09:30 – 10:00: Προσέλευση

10:00 – 11:30: The problem of robustness in the MUSA method: Theoretical developments and applications – Yannis Politis, Evangelos Grigoroudis

11:30 – 12:00: Διάλειμμα

12:00 – 13:30: A multicriteria approach for developing an evaluation model in bank branches – Constantin Zopounidis, Michael Doumpos

13:30 – 14:00: Συζήτηση – Κλείσιμο του workshop

Πίνακας 2.1: Συμμετέχοντες στο 3ο επιστημονικό workshop

Ομάδα	Ερευνητές
Ερευνητική ομάδα Πανεπιστημίου Πειραιά	Ιωάννης Σίσκος (Καθηγητής/ΠΑΠΕΙ) Διονύσης Γιαννακόπουλος (Καθηγητής/ΤΕΙ Πειραιά) Ευάγγελος Γρηγορούδης (Αν. Καθηγητής/Πολ. Κρήτης) Αθανάσιος Σπυριδάκος (Αν. Καθηγητής/ΤΕΙ Πειραιά) Νίκος Τσότσολας (Μεταδιδάκτορας/ΠΑΠΕΙ) Ιώαννης Πολίτης (Μεταδιδάκτορας/ΠΑΠΕΙ) Γεωργία Μουριάδου (Ερευνητής/ΠΑΠΕΙ)
Ερευνητική ομάδα Πολυτεχνείου Κρήτης	Κωνσταντίνος Ζοπουνίδης (Καθηγητής/Πολ. Κρήτης) Μιχάλης Δούμπος (Αν. Καθηγητής/Πολ. Κρήτης) Alexis Tsoukias (Διευθυντής Έρευνας/CNRS – LAMSADE/ Καθηγητής/Université Paris Dauphine)

Ερευνητική ομάδα Εθνικού Μετσόβιου Πολυτεχνείου	Ιωάννης Ψαρράς (Καθηγητής/ΕΜΠ) Γιώργος Μαυρωτάς (Επ. Καθηγητής, ΕΜΠ) Jose Figueira (Associate Professor, Technical University of Lisbon) Χάρης Δούκας (Μεταδιδάκτορας/ΕΜΠ) Ελευθέριος Σίσκος (Υπ. Διδάκτορας/ΕΜΠ)

Στο Παράρτημα Γ της συγκεκριμένης έκθεσης δίνονται οι παρουσιάσεις που χρησιμοποιήθηκαν σε όλη τη διάρκεια του workshop συνάντησης, σύμφωνα με το προηγούμενο πρόγραμμα.

Τέλος, θα πρέπει να σημειωθεί ότι μετά την ολοκλήρωση του 4ου Επιστημονικού Workshop, τα μέλη των ερευνητικών ομάδων είχαν τη δυνατότητα παρουσίασης ερευνητικών αποτελεσμάτων του έργου στο συνέδριο 79th Meeting of the EURO Working Group on Multicriteria Decision Making (http://www.ipta.demokritos.gr/MCDA79) το οποίο πραγματοποιήθηκε τις επόμενες ημέρες στην Αθήνα.

Παράρτημα Α: Αφίσα workshop

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

4ο Επιστημονικό Workshop
Robust MCDA

ΠΡΟΓΡΑΜΜΑ ΘΑΛΗΣ
Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια

2-3 Απριλίου 2014
Συνεδριακό Κέντρο ΤΕΙ Πειραιά
Π. Ράλλη και Θηβών 250, 12244 Αιγάλεω

ΔΙΟΡΓΑΝΩΣΗ
ΤΕΙ Πειραιά
Σχολή Διοίκησης και Οικονομίας
Τμήμα Διοίκησης Επιχειρήσεων

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης
ΕΣΠΑ 2007-2013
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Παράρτημα Β: Φυλλάδιο workshop

Ερευνητικές Ομάδες

Πανεπιστήμιο Πειραιώς

Σίσκος, Ι.	Πανεπιστήμιο Πειραιώς
Γιαννακόπουλος, Δ.	ΤΕΙ Πειραιώς
Γρηγορούδης, Ε.	Πολυτεχνείο Κρήτης
Bouyssou, D.	Université Paris Dauphine
Hurson, C.	Université de Rouen
Σπυριδάκος, Α.	ΤΕΙ Πειραιώς
Τσότσολας, Ν.	Πανεπιστήμιο Πειραιώς
Πολίτης, Ι.	Πανεπιστήμιο Πειραιώς
Χριστοδουλάκης, Ν.	Πανεπιστήμιο Πειραιώς
Μουριάδου, Γ.	Πανεπιστήμιο Πειραιώς

Πολυτεχνεί ο Κρήτης

Ζοπουνίδης, Κ.	Πολυτεχνείο Κρήτης
Ματσατσίνης, Ν.	Πολυτεχνείο Κρήτης
Δούμπος, Μ.	Πολυτεχνείο Κρήτης
Tsoukias, A.	Université Paris Dauphine
Δελιάς, Π.	ΤΕΙ Καβάλας
Μαναρώλης, Ε.	Πολυτεχνείο Κρήτης
Νίκλης, Δ.	Πολυτεχνείο Κρήτης

Εθνικό Μετσόβιο Πολυτεχνεί ο

Ψαρράς, Ι.	Εθνικό Μετσόβιο Πολυτεχνείο
Ασκούνης, Δ.	Εθνικό Μετσόβιο Πολυτεχνείο
Καραγιαννόπουλος, Κ.	Εθνικό Μετσόβιο Πολυτεχνείο
Figueira, J.	Instituto Superior Tecnico
Δούκας, Χ.	Εθνικό Μετσόβιο Πολυτεχνείο
Ξυδώνας, Π.	Εθνικό Μετσόβιο Πολυτεχνείο
Σίσκος, Ε.	Εθνικό Μετσόβιο Πολυτεχνείο

Πληροφορίες

Καθηγητής Α. Σπυριδάκος
ΤΕΙ Πειραιά
Σχολή Διοίκησης και Οικονομίας
Τμήμα Διοίκησης Επιχειρήσεων
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Website Ερευνητικού Έργου

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Συμμετέχοντα Ιδρύματα

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ
ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ
ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
Ευρωπαϊκή Ένωση
ΕΣΠΑ 2007-2013
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Τεχνολογικό Εκπαιδευτικό Ίδρυμα
ΤΕΙ
ΠΕΙΡΑΙΑ

4ο Επιστημονικό Workshop

Robust MCDA

ΠΡΟΓΡΑΜΜΑ ΘΑΛΗΣ
Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια

2-3 Απριλίου 2014
Συνεδριακό Κέντρο ΤΕΙ Πειραιά
Π. Ράλλη και Θηβών 250, 12244 Αιγάλεω

ΔΙΟΡΓΑΝΩΣΗ
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Πρόγραμμα ΘΑΛΗΣ

Το **4 ° Επιστημονικό Workshop Robust MCDA** πραγματοποιείται στα πλαίσια του έργου ΘΑΛΗΣ με τίτλο «Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια» και εντάσσεται στο σύνολο των δράσεων δημοσιότητας του έργου.

Το έργο αφορά στη μελέτη της ευστάθειας (robustness) σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια. Η έννοια της ευστάθειας αναφέρεται τόσο στη συμφωνία των παραδοχών και εκτιμήσεων που διαμορφώνουν ένα μοντέλο υποστήριξης αποφάσεων σε σχέση με τα πραγματικά χαρακτηριστικά του προβλήματος, όσο και στην ποιότητα των προτεινόμενων λύσεων σε σχέση με εναλλακτικά σενάρια για το πλαίσιο και το περιβάλλον της απόφασης.

Το αντικείμενο του έργου καλύπτει θέματα όπως:

- η ανάπτυξη διαδικασιών μέτρησης της ευστάθειας των αποτελεσμάτων και των παραμέτρων διαδικασιών πολυκριτήριας ανάλυσης,
- η μελέτη της ποιότητας των δεδομένων και της σχέσης τους με τα αποτελέσματα μιας πολυκριτήριας αξιολόγησης, και
- η ανάπτυξη μεθοδολογιών για τη διαμόρφωση λύσεων που παρουσιάζουν ευστάθεια σε μεταβολές των παραμέτρων ενός προβλήματος απόφασης και του περιβάλλοντός της.

Βασικός στόχος του έργου είναι η ανάπτυξη ενός ολοκληρωμένου θεωρητικού πλαισίου για τη μέτρηση της ευστάθειας των λύσεων που προκύπτουν από υπάρχουσες μεθοδολογίες, καθώς επίσης και η προώθηση της διεθνούς επιστημονικής έρευνας στο χώρο της επιχειρησιακής έρευνας και της πολυκριτήριας ανάλυσης.

Πρόσθετοι στόχοι του έργου αποτελούν

- η ανάπτυξη της συνεργασίας σε εθνικό και διεθνές επίπεδο σε θέματα πολυκριτήριας ανάλυσης αποφάσεων,
- η διάδοση της παραγόμενης επιστημονικής γνώσης και
- η πρακτική εφαρμογή των θεωρητικών αποτελεσμάτων της έρευνας.

Τέλος, θα πρέπει να σημειωθεί ότι στο πλαίσιο του έργου θα μελετηθεί ένα ευρύ πεδίο πρακτικών εφαρμογών από τους χώρους της περιβαλλοντικής και ενεργειακής διαχείρισης, της ανάλυσης οικονομικών και τεχνολογικών κινδύνων (διαχείριση επενδύσεων, χρηματοοικονομικός προγραμματισμός, βιομηχανική ασφάλεια, κ.ά.), της διοίκησης επιχειρήσεων (εφοδιαστική αλυσίδα, προγραμματισμός έργων, μάρκετινγκ, διοίκηση προσωπικού, κ.ά.), καθώς και των κατασκευών (κτήρια, μηχανολογικά & ηλεκτρολογικά/ηλεκτρονικά συστήματα). Σε όλα αυτά τα πεδία, η λήψη αποφάσεων χαρακτηρίζεται από την ύπαρξη πολλαπλών κριτηρίων και περιορισμών (τεχνολογικών και οικονομικών) και την αυξημένη αβεβαιότητα.

Στόχοι και Θέματα Workshop

Βασικός στόχος του Workshop είναι η παρουσίαση όχι μόνο της τρέχουσας έρευνας που έχει πραγματοποιηθεί στα πλαίσια του έργου και αφορά τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια, αλλά και του γενικότερου αντικειμένου της πολυκριτήριας ανάλυσης αποφάσεων.

Πιο συγκεκριμένα, οι στόχοι του Workshops είναι:

- η παρουσίαση των τρέχουσας ερευνητικής προσπάθειας που αφορά τη μελέτη της ευστάθειας στην πολυκριτήρια ανάλυση αποφάσεων,
- η παρουσίαση της γενικότερης θεωρίας και των πρακτικών εφαρμογών της πολυκριτήριας ανάλυσης αποφάσεων,
- η διάδοση του επιστημονικού αντικειμένου της πολυκριτήριας ανάλυσης αποφάσεων και
- η δικτύωση και η ανταλλαγή απόψεων ανάμεσα σε επιχειρησιακούς ερευνητές και στελέχη επιχειρήσεων και οργανισμών που ασχολούνται με το συγκεκριμένο αντικείμενο.

Επίσης, στα πλαίσια της συγκεκριμένου workshop δίνεται η δυνατότητα συνάντησης των μελών των ερευνητικών ομάδων.

Το Workshop περιλαμβάνει 3 ενότητες:

1. Ανάλυση ευστάθειας σε προβλήματα πολυστοχικού προγραμματισμού, συμπεριλαμβανομένων των προβλημάτων ακέραιου γραμμικού προγραμματισμού.
2. Μέτρηση της ευστάθειας σε αναλυτικές-συνθετικές προσεγγίσεις, με έμφαση στα προβλήματα λήψης ομαδικών αποφάσεων.
3. Εναλλακτικές προσεγγίσεις αντιμετώπισης προβλημάτων ευστάθειας σε συλλογικά αναλυτικά-συνθετικά μοντέλα (μέθοδος MUSA).

Τόπος και Χρόνος Διεξαγωγής

Συνεδριακό Κέντρο ΤΕΙ Πειραιά
Π. Ράλλη και Θηβών 250, 12244 Αιγάλεω
2-3 Απριλίου 2014

Συμμετοχή

Το επιστημονικό workshop είναι ανοικτό για το κοινό και στις εργασίες του μπορούν να συμμετέχει ελεύθερα χωρίς περιορισμό κάθε ενδιαφερόμενος.

Πιο συγκεκριμένα, το επιστημονικό workshop ε απευθύνονται σε ερευνητές, υποψήφιους διδάκτορες, μεταπτυχιακούς φοιτητές, κ.λπ. που εργάζονται ή σκοπεύουν να ασχοληθούν με το ευρύτερο αντικείμενο της πολυκριτήριας ανάλυσης.

Πρόγραμμα Workshop

Τετάρτη 2 Απριλίου 2014	
09:30 – 10:00:	Προσέλευση – Καλωσόρισμα από τους Διοργανωτές Καθ. Δ. Γιαννακόπουλο, Καθ. Α. Σπυριδάκο και τον Συντονιστή του έργου Καθ. Ι. Σίσκο
10:00 – 11:30:	Robustness in multi-objective project portfolio selection taking into account energy and environmental corporate responsibility and performance uncertainty – George Mavrotas, Haris Doukas, Olena Pechak, Panos Xidonas
11:30 – 12:00:	Διάλειμμα
12:30 – 13:30:	Measuring the robustness of Pareto sets in multi-objective integer programming problems – George Mavrotas, José Rui Figueira, Eleftherios Siskos
13:30 – 14:30:	Διάλειμμα
14:30 – 16:00:	Measuring robustness in aggregation-disaggregation approaches: The case of UTA methods – Nikos Tsotsolas, Athanasios Spyridakos, Denis Yannacopoulos, Nikos Christodoulakis
16:30 – 16:30:	Διάλειμμα
16:30 – 18:00:	Enriching interactivity of disaggregation-aggregation approaches through the exploitation of robustness analysis results - Athanasios Spyridakos, Yannis Siskos, Denis Yannacopoulos, Nikos Tsotsolas

Πέμπτη 3 Απριλίου 2014	
09:30 – 10:00:	Προσέλευση
10:00 – 11:30:	The problem of robustness in the MUSA method: Theoretical developments and applications – Yannis Politis, Evangelos Grigoroudis
11:30 – 12:00:	Διάλειμμα
12:00 – 13:30:	A multicriteria approach for developing an evaluation model in bank branches – Constantin Zopounidis, Michael Doumpos
13:30 – 14:00:	Συζήτηση – Κλείσιμο του workshop

Παράρτημα Γ: Παρουσιάσεις workshop

4th Workshop Robust MCDA
Athens, TEI Piraeus, April, 2-3 2014

Robustness in multi-objective project portfolio selection taking into account energy and environmental corporate responsibility and performance uncertainty

George Mavrotas
Assistant Professor
Haris Doukas
Lecturer NTUA
Olena Pechak
PhD Candidate
Panos Xidonas
Lecturer

Laboratory of Industrial & Energy Economics
Decision Lab/EPU
National Technical University of Athens

Robust MCDA

Content

- Introduction
- Methodology
  - Iterative Trichotomic Approach
  - Robustness index
- Case study
  - Energy Environmental Corporate Responsibility
- Conclusions

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Introduction

- Project portfolio selection
- Multi-objective approach
  - NPV of project
  - Energy & Environmental Corporate Responsibility (EECR) of firm
- Uncertainty on the objective function coefficients

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Aim

- To estimate the degree of certainty (robustness) of each Pareto optimal portfolio regarding its participation in the Pareto set.

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Iterative Trichotomic Approach (ITA)

- Designed to deal with uncertainty in project evaluation using a Monte Carlo simulation – Optimization approach
- Basic principle: Some projects are under all the scenarios selected (green) and some others are under all the scenarios rejected (red)
- We focus on the “in-between” projects (selected in some scenarios) which are the grey projects
- We reduce the uncertainty and repeat the Monte Carlo simulation – optimization process
- In each iteration the grey projects are reduced until they are vanished

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ITA and group decision making

- We adapt ITA to the Group Decision Making framework
- The scenarios are the decision makers
- Each one of them has his own weights
- In each iteration we have the trichotomy of the projects (green, red, grey) across the decision makers

green set	red set	grey set
Projects selected in all optimal portfolios	Projects not selected in none optimal portfolio	Projects selected in some optimal portfolios

- Converging process
- Repeat until no grey projects are present

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Allocation of projects in sets

- On each iteration we obtain an **optimal portfolio**
- Each project can be present (Xj=1) or not (Xj=0) in the optimal portfolio

		Projects					
	Optimal portfolio	**x_1**	**x_2**	**x_3**	**x_4**	**...**	**x_n**
Decision makers	**1**	1	0	0	1	...	1
	2	0	0	1	1	...	1
	3	0	0	0	1	...	0
	...	...	...	...	...	...	...
	P	1	0	0	1	...	1
		grey	**red**	**grey**	**green**		**grey**

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From projects to portfolios of projects

- Multi-objective problem → not an optimal portfolio but a set of Pareto optimal portfolios
- Instead of examining the participation of a project to the final portfolio we examine the participation of a portfolio to the final Pareto set
- Iterative
- Instead of solving an IP problem we solve a MOIP problem in each iteration

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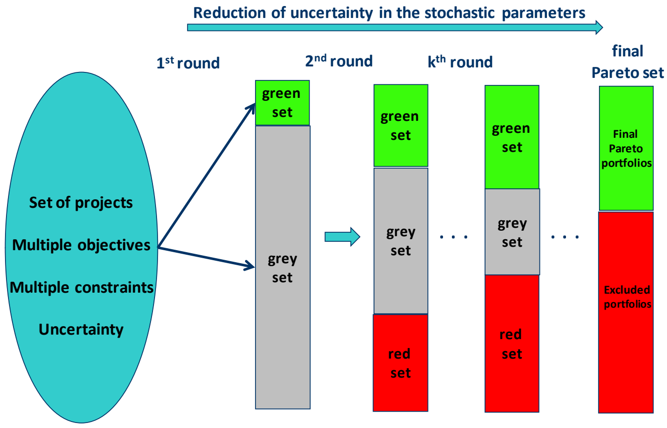
Illustration of the method



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Monte Carlo simulation - optimization

- We sample the o.f.c. from the intervals
- Create a solve a new MOIP

$$
\begin{aligned}
&\max\ Z_1^{(t)} = \sum_{i=1}^{N} c_{i1}^{(t)} X_i \\
&\ldots \\
&\max\ Z_K^{(t)} = \sum_{i=1}^{N} c_{iK}^{(t)} X_i \\
&st \\
&\mathbf{X} \in S \\
&X_i \in \{0,1\}
\end{aligned}
$$

- Exact solution with **AUGMECON2**

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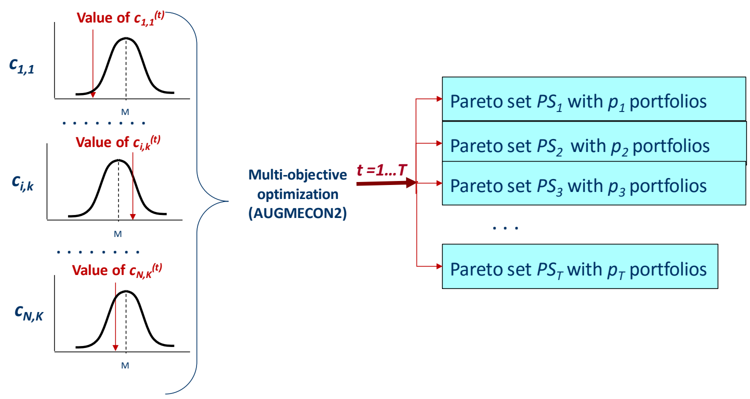
Monte Carlo simulation–optimization



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Green portfolios

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
PS_1	1	1	0	0	1	1	0	0	1	0	0
	2	0	0	1	1	0	1	0	1	0	1
	3	0	1	0	0	1	0	1	1	0	1
		...	...	...	...	...	...	...	...	...	...
	21	0	1	0	1	0	0	0	1	1	1
PS_2	1	0	0	1	1	0	1	0	1	0	1
	2	1	1	0	0	0	1	0	1	0	1
	3	1	1	0	1	0	1	1	0	0	1
		...	...	...	...	...	...	...	...	...	...
	19	0	0	1	1	1	0	0	1	0	1
		...	...	...	...	...	...	...	...	...	...
PS_{1000}	1	1	1	0	1	0	0	1	1	0	1
	2	1	0	0	1	1	1	0	1	0	1
	3	0	0	1	1	0	1	0	1	0	1
		...	...	...	...	...	...	...	...	...	...
	23	0	0	1	1	1	0	0	1	0	1

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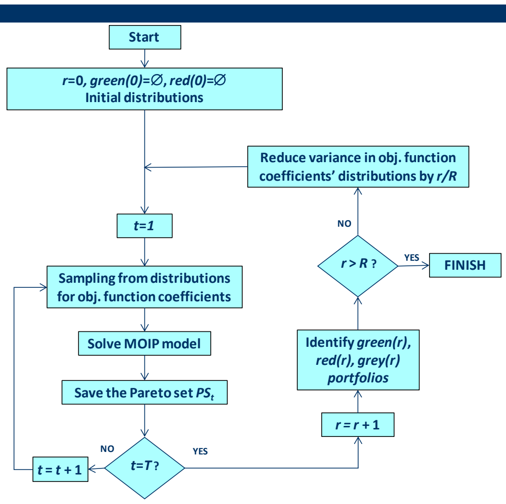
Flowchart



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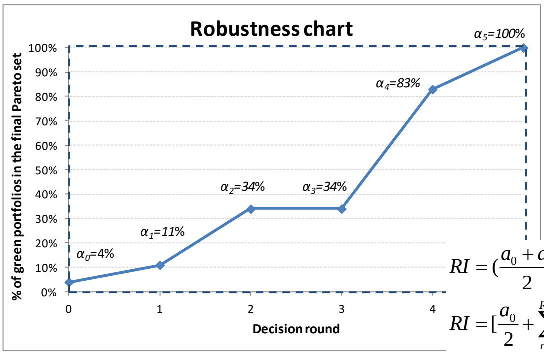
Robustness chart - Robustness index



$$RI = \left(\frac{a_0 + a_1}{2} + \frac{a_1 + a_2}{2} + \ldots + \frac{a_{R-1} + a_R}{2}\right) / R$$

$$RI = \left[\frac{a_0}{2} + \sum_{r=1}^{R-1} a_r + \frac{a_R}{2}\right] / R$$

$$RI = \left[\frac{a_0}{2} + \sum_{r=1}^{R-1} a_r + \frac{1}{2}\right] / R$$

For i-th portfolio: $RD_i = \dfrac{R - r_i}{R}$

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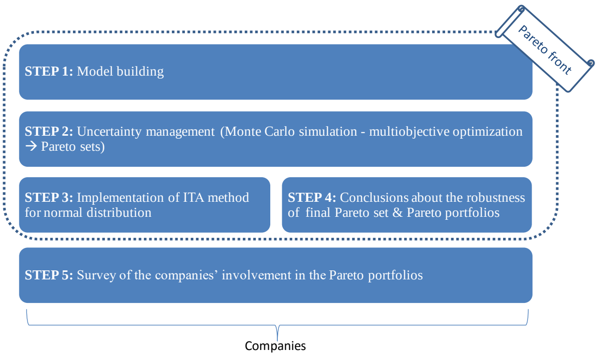
Outline of the method



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Case study

- 40 projects
- 2 Criteria
  - NPV
  - EECR
- Segmentation constraints (sectoral, geographical)
  - no sector or region is allowed to have more than half of the total approved applications
  - all sectors and areas will be funded with at least 10% of the total budget

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EECR score

Criteria	Description
C1: Management Commitment	The degree to which Management of a firm prioritizes actions related to the energy and environmental corporate policy, sets specific targets and corresponding time schedule for their accomplishment
C2: Monitoring Progress and related impact	The degree to which a firm adopts procedures and protocols for monitoring the set of targets, specific progress made in each related activity and the corresponding impact in companies operation and activation in the market.
C3: Participation in Dissemination Activities	Reflects firms' participation in dissemination activities in broader community, including among others, educational and information activities regarding environmental practices, organization of workshops, conferences and other events, and sponsorships
C4: Promotion of Renewable Energy	Refers to the enterprise involvement for investment in projects and initiatives related to renewable energy sources -wind power, solar power (thermal, photovoltaic and concentrated), hydro-electric power, tidal power, geothermal energy and biomass.
C5: Promotion of Energy Efficiency	The extent to which a firm incorporates initiatives to provide energy-efficient products and services, to reduce direct and indirect energy consumption and other energy conservation practices and technological improvements.
C6: Waste and Water Management	This criterion demonstrates the effort of firms in reducing total water use or discharge and the adoption of waste management activities.

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Model

portfolio's NPV: $max\ Z_1 = \sum_{i=1}^{N} npv_i X_i$

portfolio's *EECR*: $max\ Z_2 = \sum_{i=1}^{N} eecr_i X_i$

st

$$\sum_{i=1}^{N} \text{cost}_i\ X_i \leq avb$$

$$\sum_{i\in R} X_i \leq 0.5 \times \sum_{i=1}^{N} X_i$$

$$\sum_{i\in S} X_i \leq 0.5 \times \sum_{i=1}^{N} X_i$$

$$\sum_{i\in S} \text{cost}_i X_i \geq 0.1 \times \sum_{i=1}^{N} \text{cost}_i X_i$$

$$\sum_{i\in R} \text{cost}_i X_i \geq 0.1 \times \sum_{i=1}^{N} \text{cost}_i X_i$$

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Results

		green	red	grey
σ =5%	round1	4	0	394
σ =4%	round2	4	109	285
σ =3%	round3	5	215	178
σ =2%	round4	9	275	114
σ =1%	round5	16	324	54
σ =0%	round6	31	367	0

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	

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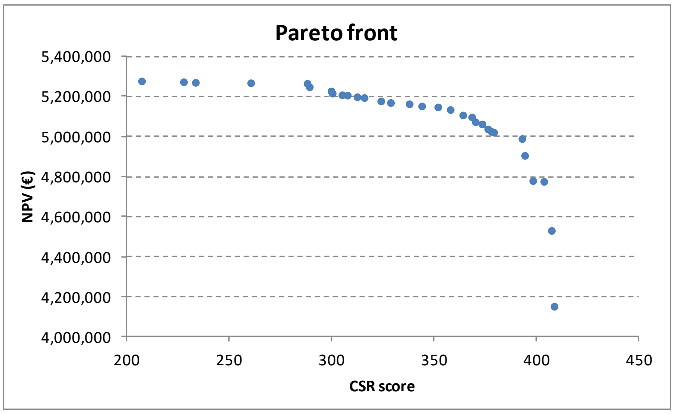
Pareto front



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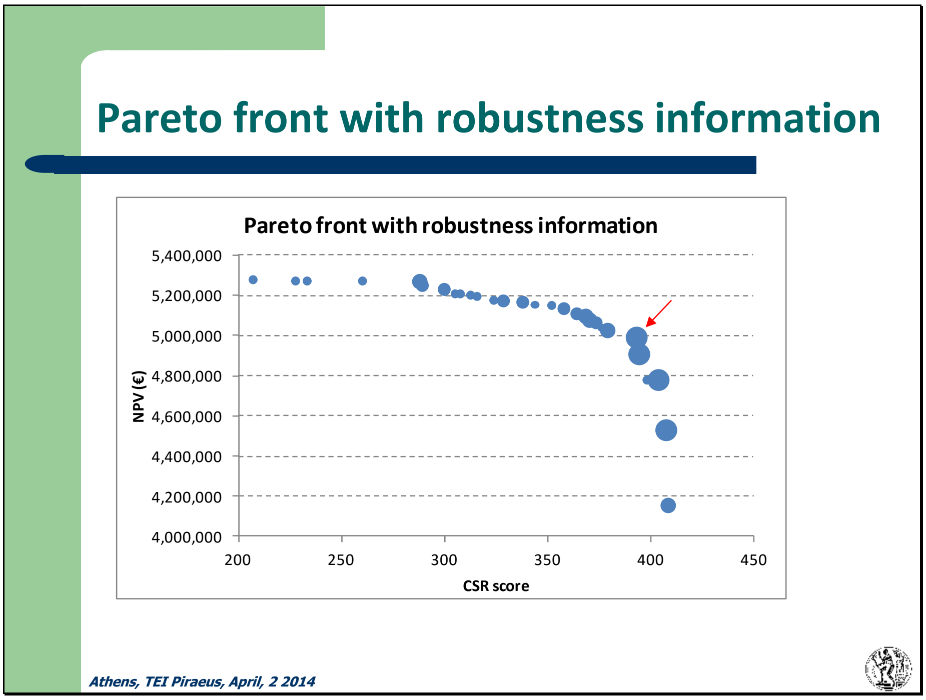
Pareto front with robustness information
Pareto front with robustness information
NPV (€)
5,400,000
5,200,000
5,000,000
4,800,000
4,600,000
4,400,000
4,200,000
4,000,000
200
250
300
350
400
450
CSR score
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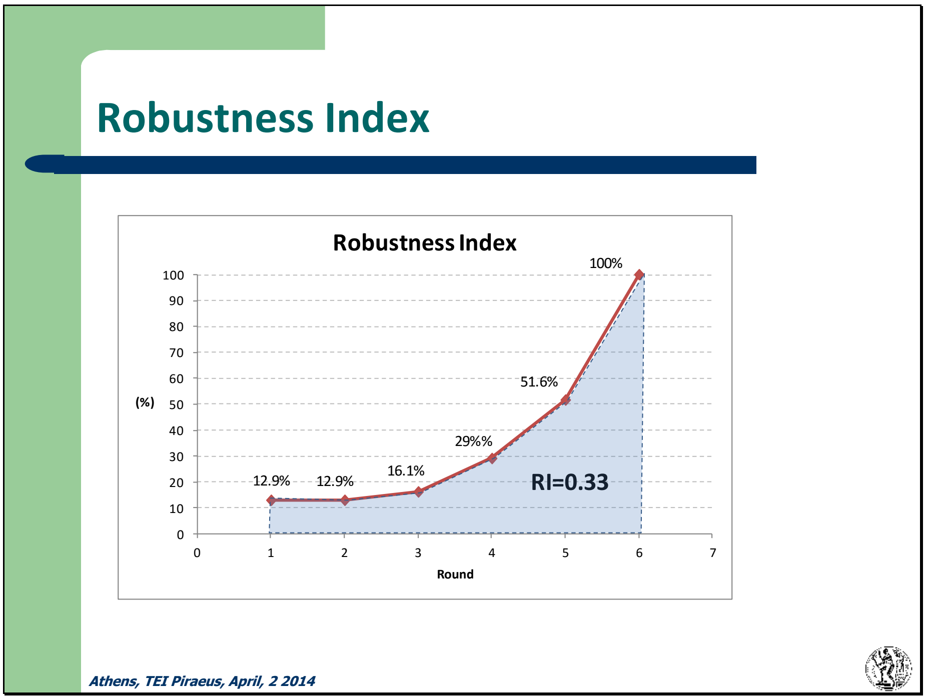
Robustness Index
Robustness Index
(%)
100
90
80
70
60
50
40
30
20
10
0
12.9%
12.9%
16.1%
29%%
51.6%
100%
RI=0.33
0
1
2
3
4
5
6
7
Round
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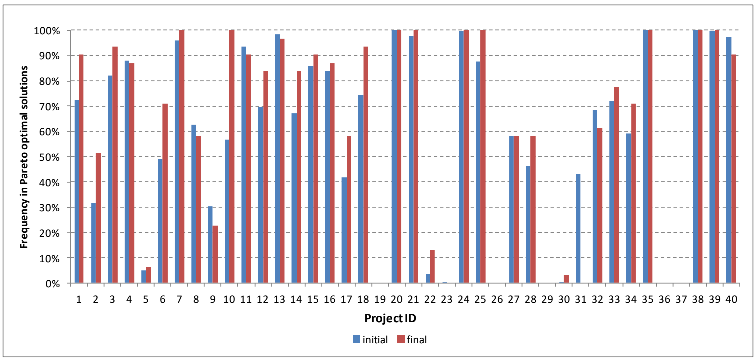
Project information



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Concluding remarks

- ITA method can be adopted to the multi-objective optimization case (Pareto optimal portfolios) for dealing with uncertainty in parameters
- Combination of Monte Carlo optimization – multi-objective programming (AUGMECON2)
- Incorporation of EECR as additional objective function give advantage to environmental conscious firms
- Useful tools for effective decision making

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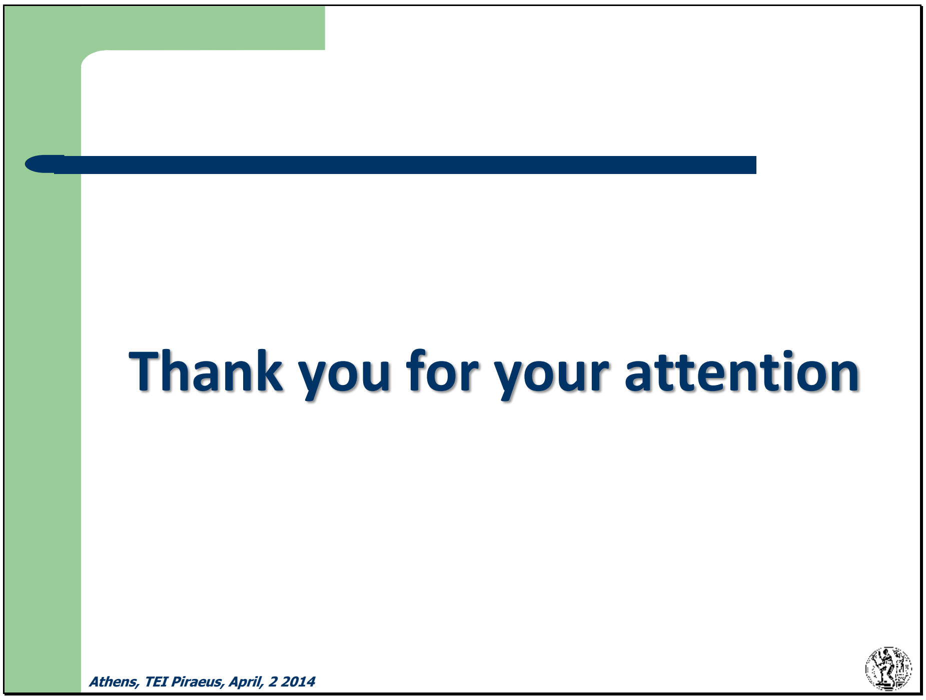
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4th Workshop of THALES
Athens, 2-3 April 2014

Assessing the robustness of Pareto sets in Multi-Objective Integer Programming problems

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Robust MCDA

Content

- Introduction
- Methodology
  - Monte Carlo simulation – Optimization
  - Robustness index
- Numerical example
- Case study
- Conclusions

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Introduction

- Robustness is related to the parameter uncertainty or imprecision of an optimization model
- Solutions to optimization problems can exhibit remarkable sensitivity to perturbations in parameters of the problem
- Robustness can be defined as a degree to which a solution is insensitive to underlying assumptions within a model.
- The underlying assumptions are the values of the model parameters
- In this work we deal with perturbations on the objective function coefficients

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Aim

- The aim of the work is to assess the robustness of the Pareto set in Multi-Objective Integer Programming (MOIP) problems based on objective function coefficients' perturbations
- Identify regions in the Pareto front that are more robust than others
- Assess the robustness of Pareto Optimal Solutions (POS)

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Reference Pareto Set

- The original Pareto set that we want to measure its robustness is called reference Pareto set and is denoted with "*"
  - The reference Pareto set is PS*
  - The reference Pareto front is PF*
  - The reference Pareto optimal Solutions are POS*
- The reference Pareto set corresponds to the MOIP model with the original objective function coefficients

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Reference model

Reference model

$$\max\ z_1 = \sum_{i=1}^{N} c_{i1} X_i$$

$$\ldots$$

$$\max\ z_K = \sum_{i=1}^{N} c_{iK} X_i$$

$$st$$

$$\mathbf{X} \in S$$

$$X_i \in \{0,1\}$$

We take intervals around the original objective function coefficients using a perturbation parameter *a*

$$[c_{ik} + \alpha \times c_{ik},\ c_{ik} - \alpha \times c_{ik}]$$

$$a \in [5\%, 20\%]$$

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Monte Carlo simulation - optimization

- We sample the o.f.c. from the intervals
- Create a solve a new MOIP

$$\begin{aligned}
&\max\ Z_1^{(t)} = \sum_{i=1}^{N} c_{i1}^{(t)} X_i \\
&\ldots \\
&\max\ Z_K^{(t)} = \sum_{i=1}^{N} c_{iK}^{(t)} X_i \\
&st \\
&\mathbf{X} \in S \\
&X_i \in \{0,1\}
\end{aligned}$$

- Exact solution with **AUGMECON2**

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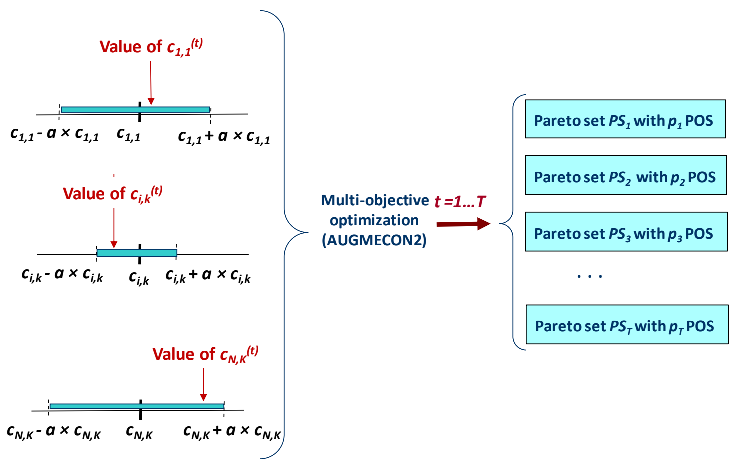
Monte Carlo simulation–optimization



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Coding the Pareto Optimal Solutions

- In MOIP problems every POS is a vector of 0 and 1
- Coding: $$code_p = \sum_{i=1}^{N} 2^{(i-1)} \times \bar{X}_i$$

Table 1. Example of POS coding

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	code
POS 1	0	0	1	0	1	1	1	0	0	1	628
POS 2	0	1	0	1	1	1	1	0	0	0	122
POS 3	0	1	1	1	0	0	1	0	0	1	590
POS 4	0	0	1	0	1	1	1	0	0	0	116
POS 5	1	1	1	0	1	0	1	0	1	1	855

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Robustness Index

- For the *p*-th POS* we count its frequency (S_p) across the *T* Pareto sets

$$RI_p = \frac{S_p}{T}$$

- For the entire PS* we have the total robustnes index (TRI) defined as:

$$TRI = \frac{\sum_{p=1}^{|PS^*|} RI_p}{|PS^*|}$$

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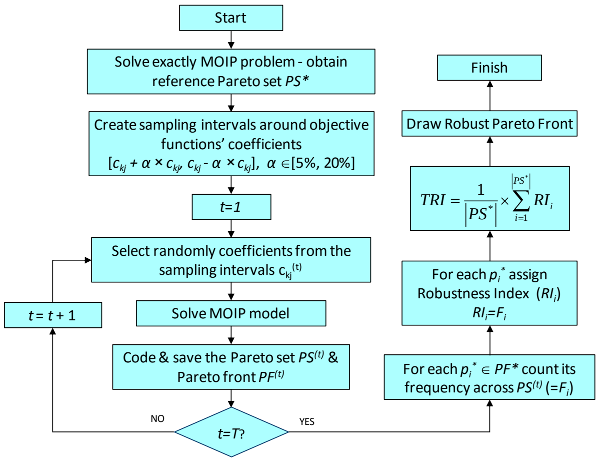
Flowchart of the algorithm



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Numerical example

- Knapsack problem with 2 objective functions, 50 binary variables and one constraint
- The reference set has 54 POS*
- 1000 Monte Carlo iterations
  - → *disturbance parameter a*=5%
  - → (sampling and AUGMECON2 → 3h 05' 12").
- RI_p varies from 0.273 to 0.998

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PF* and robustness indices

#	Z_1	Z_2	RI		#	Z_1	Z_2	RI
1	17962	14727	40.40%		28	17224	18300	99.80%
2	17956	14756	32.50%		29	17023	18376	66.20%
3	17953	14967	37.90%		30	17015	18474	99.70%
4	17947	14996	28.90%		31	16852	18493	63.50%
5	17942	15336	54.80%		32	16811	18520	49.30%
6	17927	15863	85.00%		33	16809	18549	81.20%
7	17891	16121	95.40%		34	16790	18593	88.40%
8	17850	16148	40.40%		35	16763	18687	99.10%
9	17844	16226	47.30%		36	16538	18806	99.60%
10	17833	16438	69.80%		37	16517	18822	74.90%
11	17803	16495	35.30%		38	16364	18829	44.30%
12	17795	16583	31.90%		39	16334	18886	99.40%
13	17794	16735	96.20%		40	16176	18969	99.50%
14	17729	16857	66.10%		41	16088	19021	98.20%
15	17714	16878	56.90%		42	16024	19029	52.60%
16	17700	16966	88.30%		43	16003	19045	67.00%
17	17657	17024	48.30%		44	15797	19120	99.40%
18	17644	17149	67.80%		45	15778	19164	96.40%
19	17621	17282	79.20%		46	15736	19170	49.20%
20	17590	17453	90.80%		47	15436	19227	61.70%
21	17532	17476	27.20%		48	15415	19319	99.40%
22	17531	17569	41.80%		49	15169	19352	75.20%
23	17523	17683	46.90%		50	14971	19359	40.00%
24	17520	17781	57.10%		51	14950	19375	53.10%
25	17516	17951	99.60%		52	14923	19383	55.40%
26	17431	17975	94.50%		53	14904	19427	96.40%
27	17231	18032	46.20%		54	13880	19487	99.80%

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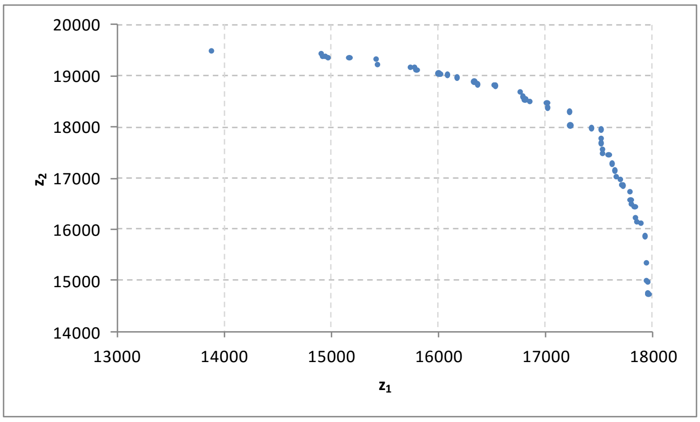
Pareto front



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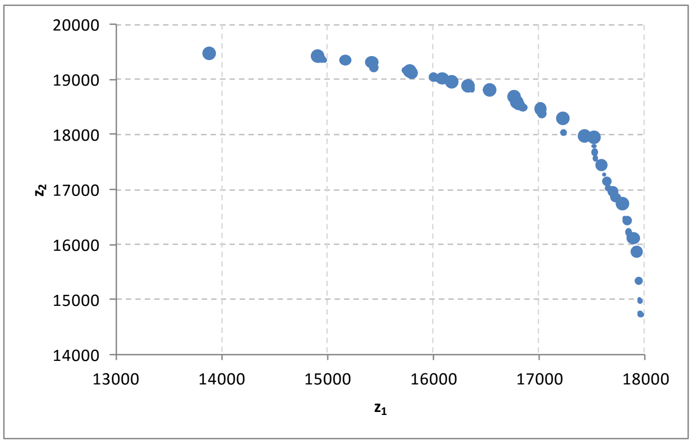
Pareto front with robustness information



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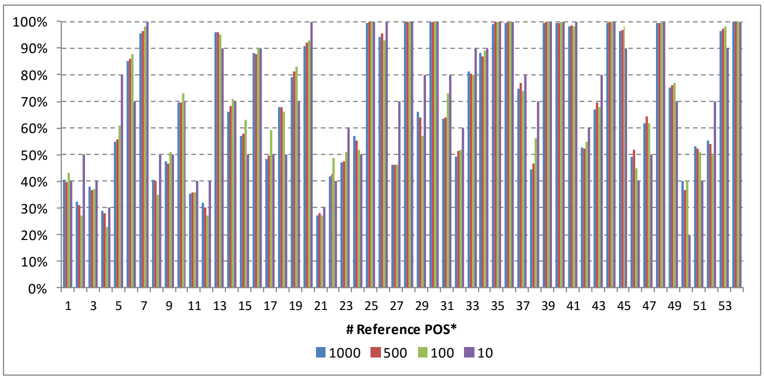
Different number of iterations in MC



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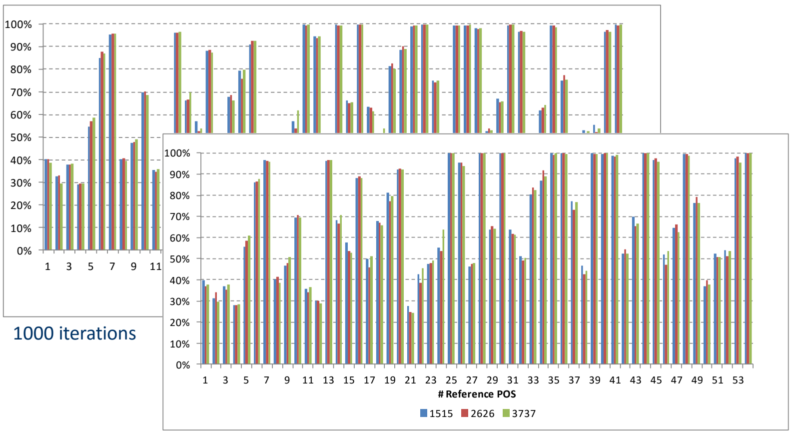
Different seed points in random generator



1000 iterations

500 iterations

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Case study

- Capital Budgeting problem with research proposals in a University (Academic project selection)
- 150 research proposals from 9 departments
  - Research is characterized as either “Basic” or “Applied”
- Available budget 3M€, total cost for 150 proposals 13.2M€
- Two criteria:
  - Usefulness [1-10]
  - Faculty sufficiency [1-10]
- Distribution constraints

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Distribution constraints

- Department representation

Lower and upper bounds of the budget attributed to each department

Department	A	B	C	D	E	F	G	H	I
Lower	14%	11%	4%	8%	4%	11%	10%	5%	10%
Upper	23%	19%	6%	13%	6%	18%	16%	9%	16%

- Basic/Applied research
  - ➔ At least 30% of projects from basic research

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Model

$$\max z_1 = \sum_{i=1}^{150} uf_i \times X_i$$

$$\max z_2 = \sum_{i=1}^{150} fs_i \times X_i$$

st

$$\sum_{i=1}^{150} \cos t_i \times X_i = TC$$

$$TC \leq 3000$$

$$\sum_{i \in D(j)} \cos t_i \times X_i \leq ub_j \times TC \quad for\ j = A, B, C, D, E, F, G, H, I$$

$$\sum_{i \in D(j)} \cos t_i \times X_i \geq lb_j \times TC \quad for\ j = A, B, C, D, E, F, G, H, I$$

$$\sum_{i=1}^{150} X_i = N$$

$$\sum_{i \in Basic} X_i \geq 0.3 \times N$$

Robustness analysis

Perturbations of o.f.c. to
$[uf_i\text{-}1,\ uf_i\text{+}1]$
$[fs_i\text{-}1,\ fs_i\text{+}1]$

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PF* and Robustness indices

#	z_1	z_2	RI	#	z_1	z_2	RI	#	z_1	z_2	RI
1	334	224	2.20%	23	311	278	2.50%	45	287	307	4.80%
2	333	231	2.00%	24	310	279	1.40%	46	286	308	3.40%
3	332	234	2.20%	25	309	280	0.70%	47	284	309	2.60%
4	331	239	3.30%	26	308	282	1.90%	48	283	311	6.20%
5	330	241	1.60%	27	307	283	1.10%	49	281	312	1.60%
6	329	244	3.60%	28	306	284	1.30%	50	280	314	13.00%
7	328	247	3.30%	29	305	287	3.70%	51	279	315	10.90%
8	327	249	3.00%	30	303	288	2.40%	52	276	316	3.50%
9	326	250	0.60%	31	302	289	1.40%	53	275	318	17.50%
10	325	254	4.20%	32	301	290	1.10%	54	272	319	5.70%
11	323	257	2.20%	33	300	291	0.50%	55	269	321	6.20%
12	322	258	0.30%	34	299	292	0.40%	56	268	322	11.50%
13	321	261	2.10%	35	298	294	1.70%	57	264	324	11.10%
14	320	262	0.70%	36	297	295	1.20%	58	261	325	5.30%
15	319	264	1.50%	37	296	296	1.00%	59	259	326	7.00%
16	318	266	1.30%	38	295	297	0.40%	60	257	328	17.80%
17	317	268	1.40%	39	294	299	2.30%	61	251	329	3.90%
18	316	270	1.70%	40	293	300	3.20%	62	248	331	13.80%
19	315	271	1.40%	41	292	301	2.30%	63	243	332	5.90%
20	314	272	1.20%	42	291	302	1.40%	64	240	333	4.80%
21	313	274	1.40%	43	290	303	1.30%	65	232	334	2.00%
22	312	276	2.00%	44	289	305	4.20%	66	219	335	1.20%

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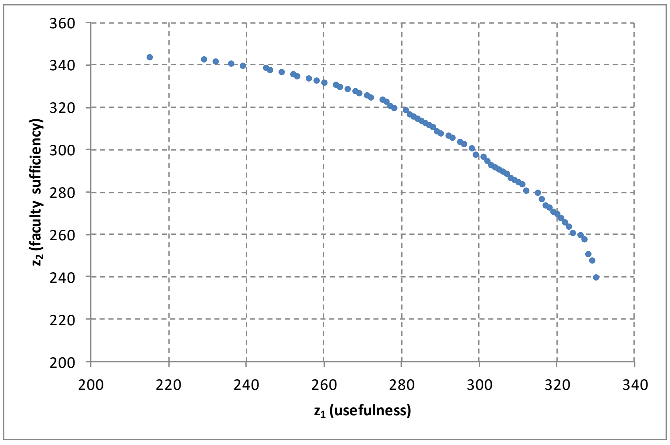
PF* illustration



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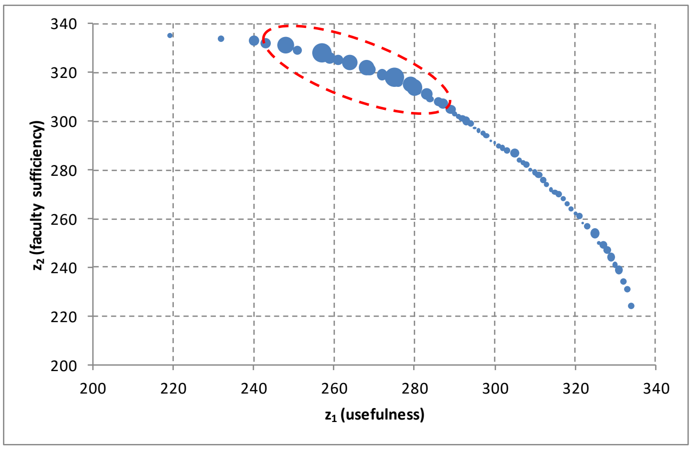
PF* with robustness information



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Concluding remarks

- We deal with Robustness of POS in MOIP problems based on uncertainty/imprecision of objective function coefficients
- Perturbations/Monte Carlo simulation
- AUGMECON2 for exact solution of MOIP problems
- Computational demanding process but provides insightful results (RI, TRI)
- Pareto front with robustness information bubble chart

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Future research

- Incorporate in the same manner more parameters in addition to o.f.c. (technological coefficients in constraints)
- Expand to more than two dimensions
  - → First results…

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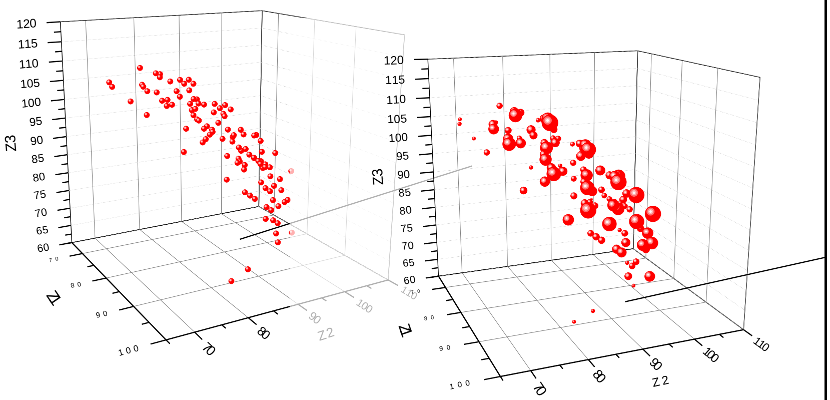
Future research (2)



3 obj, 50 var, 20 constr → 110 POS*

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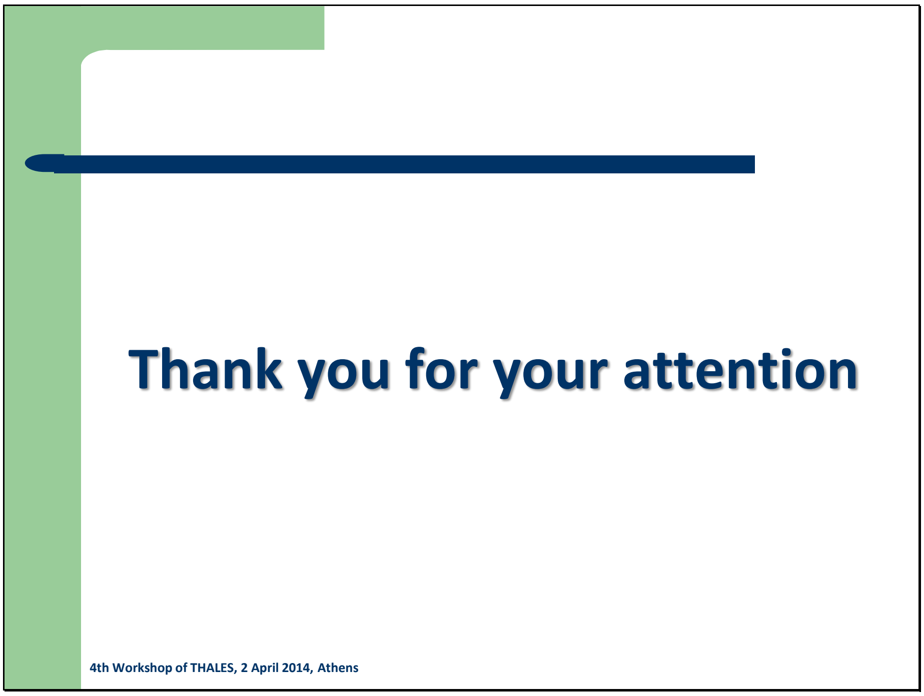
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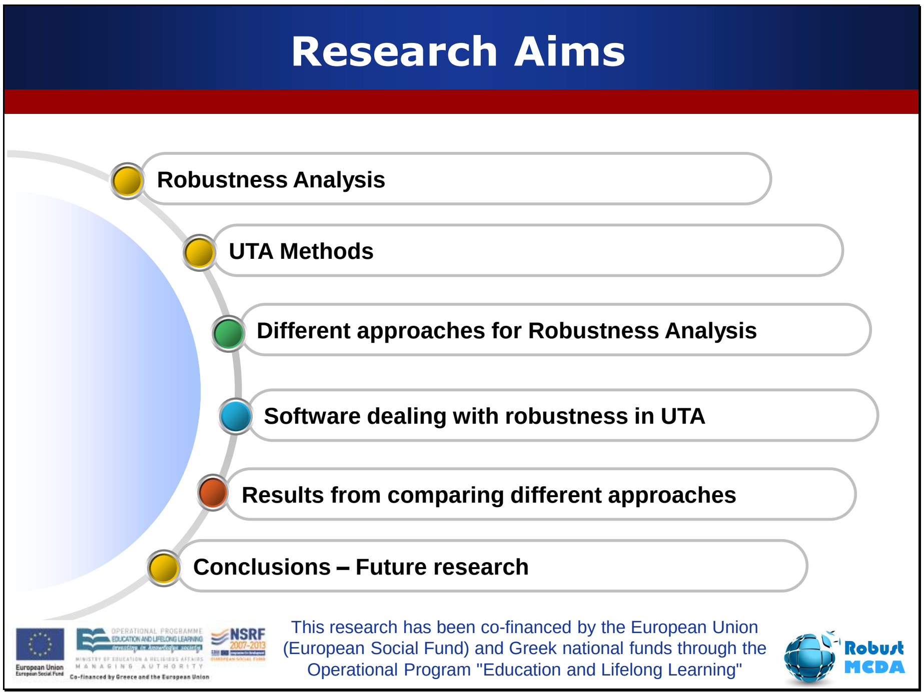
Measuring robustness in disaggregation - aggregation approaches:
The case of UTA methods
N. Tsotsolas, A. Spyridakos, D. Yannacopoulos, N. Christodoulakis
Robust MCDA
ΕΣΠΑ 2007-2013


Research Aims
Robustness Analysis
UTA Methods
Different approaches for Robustness Analysis
Software dealing with robustness in UTA
Results from comparing different approaches
Conclusions – Future research
NSRF 2007-2013
This research has been co-financed by the European Union (European Social Fund) and Greek national funds through the Operational Program "Education and Lifelong Learning"
Robust MCDA

The notion of robustness in OR and DM

- Under a general discussion, Roy (2008 & 2010) assigns to robustness the role of a tool that supports the analysts against phenomena of "*approaches*" and "*zones of ignorance*"
- It's necessary for the analysts to take into consideration that the decisions they try to reach will be:
  - applied into the real world which will be probably not 100% compatible with the developed model
  - actually evaluated according to a value system which might not also be in total compliance with the corresponding value system which was used for the development and application of the model

model **vs** reality

EURO XXVI, 26th European Conference on Operational Research, Rome, July 2013

Issues related to robustness

- When a decision model could be considered as reliable (analyst's point of view)?
- How to measure the robustness of a decision model?
- How robustness indicators could be increased?
- Is a decision model acceptable (DM's point of view)?

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The need for robustness analysis

- The stability of a model or/and of a solution should be assessed and evaluated each time
- The analyst shall be able to have a clear picture regarding the reliability of the produced results
- Stability and reliability shall be expressed using measures which are understandable by the analyst and the decision maker
- Based on these measures the decision maker may accept or reject the proposed decision model

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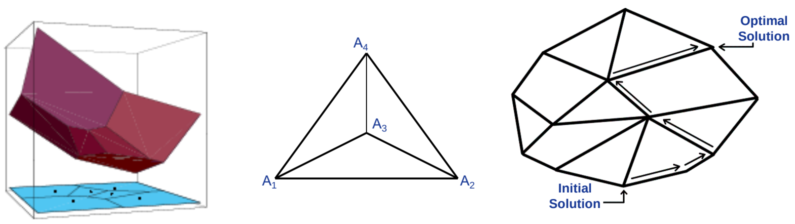
Post-optimal robustness analysis in LP

- The Linear Programming can be directly related to the geometry and graph theory.
- As for the geometry of the relationship lies in the fact that a system of inequalities (constraints of LP) define a convex hyper-polyhedron (which is usually bounded). A linear system of *n* variables can be represented by a convex polyhedron of *n*-dimensions
- According to this approach, the search of solutions of LP is equivalent to the transition from one vertex of the hyper-polyhedron to another. In other words, the basic feasible solutions of LP correspond to the vertices of the hyper-polyhedron.



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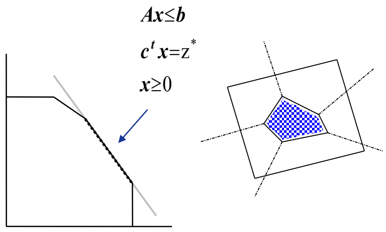
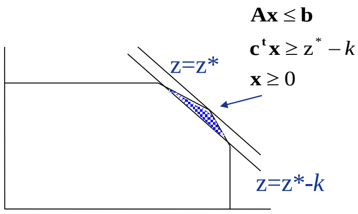
Multiple optimal/near-optimal solutions in LP

$$\begin{cases} [\max] z = \mathbf{c}^t \mathbf{x} \\ \quad \text{s.t.} \\ \mathbf{A}\mathbf{x} \le \mathbf{b} \\ \mathbf{x} \ge \mathbf{0} \end{cases}$$





Multiple Optimal Solutions **Near- Optimal Solutions**

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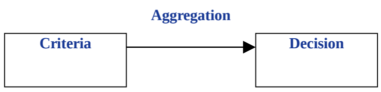
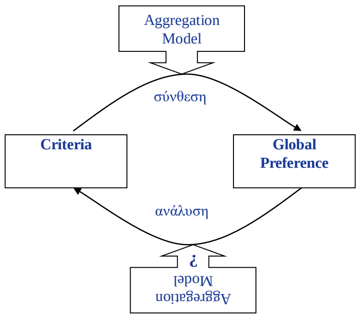
Aggregation - disaggregation approaches in MCDA



Classic aggregation approach for decision making



Aggregation – disaggregation approach for decision making

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Reference Actions A_R

The clarification of the DM's global preference necessitates the use of a set of reference actions A_R. Usually, this set could be:

1. A set of past decision alternatives (A_R : past actions)
2. A subset of actions, especially when A is large $(A_R \subset A)$
3. A set of fictitious actions, consisting of performances on the criteria, which can be easily judged by the decision-maker to perform global comparisons (A_R : fictitious actions)
4. In each of the above cases, the DM is asked to externalize and/or confirm his/her global preferences on the set A_R taking into account the performances of the reference actions on all criteria.

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The UTA Method(s) (1)

Principle

- The UTA (UTilités Additives) method proposed by Jacquet-Lagrèze and Siskos (1982) aims at **inferring one or more additive value functions** from a given ranking on a reference set A_R.

- The method uses special linear programming techniques to assess these functions so that the ranking(s) obtained through these functions on A_R is (are) as consistent as possible with the given one.

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The UTA Method(s) (2)

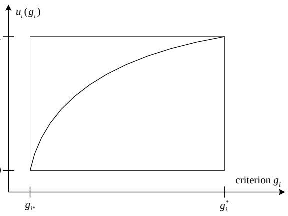
The additive value model

- The criteria aggregation model in UTA is assumed to be an additive value function of the following form:

$$u(\mathbf{g}) = \sum_{i=1}^{n} p_i u_i(g_i)$$

subject to normalization constraints:

$$\begin{cases} \sum_{i=1}^{n} p_i = 1 \\ u_i(g_{i*}) = 0, u_i(g_i^*) = 1 \ \forall \ i = 1,2,\ldots,n \end{cases}$$



where $u_i, i = 1,2,\ldots,n$, are non-decreasing real valued functions, named marginal value functions, which are normalized between 0 and 1, and p_i is the weight of u_i.

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The UTA Method(s) (3)

- Both the marginal and the global value functions have the monotonicity property of the true criterion. For instance, in the case of the global value function the following properties hold:

$$\begin{cases} u[\mathbf{g}(a)] > u[\mathbf{g}(b)] \Leftrightarrow a \succ b \ (preference) \\ u[\mathbf{g}(a)] = u[\mathbf{g}(b)] \Leftrightarrow a \sim b \ (indifference) \end{cases}$$

- The UTA method infers an unweighted equivalent form of the additive value function:

$$u(\mathbf{g}) = \sum_{i=1}^{n} u_i(g_i)$$

subject to normalization constraints:

$$\begin{cases} \sum_{i=1}^{n} u_i(g_i^*) = 1 \\ u_i(g_{i*}) = 0 \ \forall \ i = 1,2,\ldots,n \end{cases}$$

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The UTASTAR algorithm (1)

Principle

- The UTASTAR method proposed by Siskos and Yannacopoulos (1985) is an improved version of the original UTA method.
- In the original version of UTA (Jacquet-Lagrèze and Siskos, 1982), for each reference action $a \in A_R$, a single error $\sigma (a)$ is introduced to be minimized. This error function is not sufficient to minimize completely the dispersion of points all around the regression curve. The problem is posed by points situated on the right of the curve, from which it would be suitable to subtract an amount of value/utility and not increase the values/utilities of the others.

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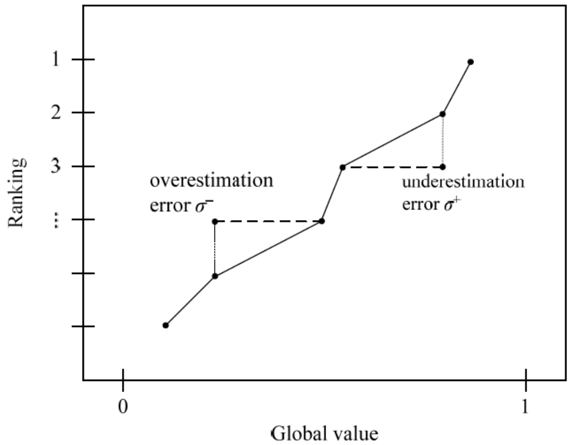
The UTASTAR algorithm (2)



Ordinal regression curve (ranking versus global value)

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The UTASTAR algorithm (3)

Initialization

- In UTASTAR method, Siskos and Yannacopoulos (1985) introduced a double positive error function:

$$u'[\boldsymbol{g}(a)] = \sum_{i=1}^{n} u_i[g_i(a)] - \sigma^+(a) + \sigma^-(a) \; \forall a \in A_{\mathfrak{R}}$$

where σ^+ and σ^- are the overestimation and the underestimation error respectively.

- Moreover, another important modification concerns the monotonicity constraints of the criteria, which are taken into account through the transformations:

$$w_{ij} = u_i\left(g_i^{j+1}\right) - u_i\left(g_i^j\right) \geq 0 \; \forall i = 1,2,\ldots,n \text{ and } j = 1,2,\ldots,a_i - 1$$

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The UTASTAR algorithm (4)

The algorithm

Step 1:

- Express the global value of reference actions $u[\boldsymbol{g}(a_k)]$, $k=1,2,\ldots,n$, first in terms of marginal values $u_i(a_i)$, and then in terms of variables w_{ij}, by means of the following expressions:

$$\begin{cases} u_i\left(g_i^1\right) = 0 \; \forall i = 1,2,\ldots,n \\ u_i\left(g_i^j\right) = \sum_{t=1}^{j-1} w_{ij} \; \forall i = 1,2,\ldots,n \text{ and } j = 2,3,\ldots,a_i - 1 \end{cases}$$

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The UTASTAR algorithm (5)

The algorithm

Step 2:

- Introduce two error functions σ^+ and σ^- on A_R by writing for each pair of consecutive actions in the ranking the analytic expressions:

$$\Delta(a_k, a_{k+1}) = u[\mathbf{g}(a_k)] - \sigma^+(a_k) + \sigma^-(a_k) - u[\mathbf{g}(a_{k+1})] + \sigma^+(a_{k+1}) - \sigma^-(a_{k+1})$$

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The UTASTAR algorithm (6)

The algorithm

Step 3:

- Solve the linear program:

$$\begin{cases} [min]z = \sum_{k=1}^{m}\left[\sigma^+(a_k) + \sigma^-(a_k)\right] \\ \text{subject to} \\ \left.\begin{array}{l} \Delta(a_k, a_{k+1}) \geq \delta \text{ if } a_k \succ a_{k+1} \\ \Delta(a_k, a_{k+1}) = 0 \text{ if } a_k \sim a_{k+1} \end{array}\right\} \forall\, k \\ \sum_{i=1}^{n}\sum_{j=1}^{a_i-1} w_{ij} = 1 \\ w_{ij} \geq 0, \sigma^+(a_k) \geq 0, \sigma^-(a_k) \geq 0 \;\forall\, i, j \text{ and } k \end{cases}$$

with δ a small positive number

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The UTASTAR algorithm (7)

The algorithm

Step 4:

- Test the existence of multiple or near optimal solutions of the linear program (stability/robustness analysis); in case of non uniqueness, find the mean additive value function of those (near) optimal solutions which maximize the objective functions:

$$\sum_{k=1}^{m}\left[\sigma^{+}(a_k)+\sigma^{-}(a_k)\right]\leq z^{*}+\varepsilon$$

where $z*$ is the optimal value of the LP in step 3 and ε a very small positive number.

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UTA II (1)

First step: The marginal value functions are built outside the UTA algorithm, by techniques such as:

a) techniques based on MAUT theory and described by Keeney and Raiffa (1976), and Klein *et al*. (1985),
b) MACBETH method (Bana e Costa and Vansnick, 1994, 1997; Bana e Costa *et al*., 2001),
c) Quasi-UTA method by Beuthe *et al*. (2000), that uses "recursive exponential" marginal value functions, and
d) MIIDAS system (see section 4) that combines artificial intelligence and visual procedures in order to extract the DM's preferences (Siskos *et al*., 1999).

Second step: The DM is asked to give a global ranking of alternatives in a similar way as in the basic UTA method. From this information, the problem may be formulated via a LP, in order to **assess only the weighting factors** of the criteria (scaling constants of criteria).

$$\Delta(a,b) = \sum_{i=1}^{n} p_i \left\{u_i[g_i(a)] - u_i[g_i(b)]\right\} - \sigma^{+}(a) + \sigma^{-}(a) + \sigma^{+}(b) - \sigma^{-}(b)$$

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UTA II (2)

Solving the following LP:

$$
\begin{cases}
[\min]F = \sum_{a \in A_R} \left[\sigma^{+}(a) + \sigma^{-}(a) \right] \\
\text{subject to} \\
\Delta(a,b) \geq \delta & \text{if } a \succ b \\
\Delta(a,b) = 0 & \text{if } a \sim b \\
\sum_{i=1}^{n} p_i = 1 \\
p_i \geq 0,\ \sigma^{+}(a) \geq 0,\ \sigma^{-}(a) \geq 0 \quad \forall a \in A_R,\ \forall i
\end{cases}
$$

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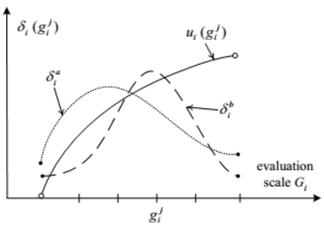
Stochastic UTA method

- Within the framework of multicriteria decision-aid under uncertainty, Siskos (1983) developed a specific version of UTA (Stochastic UTA), in which the aggregation model to infer from a reference ranking is an additive utility function of the form:

$$u(\boldsymbol{\delta}^{\alpha}) = \sum_{i} \sum_{j} \delta_i^a (g_i^j) u_i (g_i^j)$$

where δ_i^a is the distributional evaluation of action *α* on the *i*-th criterion, $\delta_i^a(g_i^j)$ is the probability that the performance of action *α* on the *i*-th criterion is g_i^j, $u_i(g_i^j)$ is the marginal value of the performance g_i^j, $\boldsymbol{\delta}^{\alpha}$ is the vector of distributional evaluations of action *α* and $u(\boldsymbol{\delta}^{\alpha})$ is the global utility of action *α*.



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Basic Steps in UTA

1. Infer a representative additive value model.
2. Remove inconsistencies
3. Establish a robustness measure
4. If the robustness measure is judged satisfactory by the analyst, the model is proposed to the DM for application on the set A. Otherwise, go to 5.
5. Apply several rules of robustness analysis and go to 3.

Robustness issues in UTA:

(i) How accurate is the estimation of the barycenter of the post-optimal solutions?

(ii) Estimate stability measures which can be easily interpreted by the analyst and communicated to the DM

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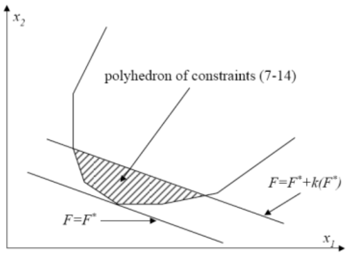
Stability/robustness analysis in UTA

- The last step of UTA algorithm is to test the existence of multiple or near optimal solutions of the linear program; in case of non uniqueness, we shall calculate the mean additive value function (barycenter) of those (multiple or near) optimal solutions which satisfy the constraint:

$$\sum_{k=1}^{m}\left[\sigma^{+}(a_k)+\sigma^{-}(a_k)\right]\leq z^{*}+\varepsilon$$

where z^* is the optimal value of the UTA LP and ε a very small positive number.



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Finding multiple optimal solutions in LP

- Categories of algorithms finding multiple solutions when proceed with post-optimality analysis:
  - Analytical algorithms which promise complete search of all basic feasible solutions of a hyper-polyhedron. Within the first group we find two sub-categories of algorithms.
    - Pivoting methods based on Dantzig's Simplex approach.
    - Non-pivoting methods that do not use the Simplex approach but use elements of the theory of geometry based on the properties of intersections between hyper-planes and hyper-polyhedron.
  - Heuristic algorithms which do not intend to find all solutions of a basic hyper-polyhedron but a representative set of these using various approaches.

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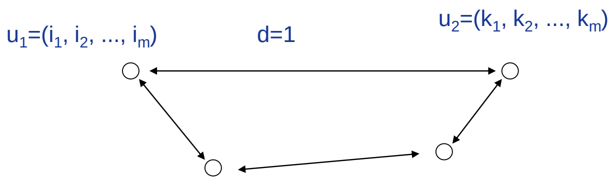
Manas – Nedoma Algorithm

- The V (set of nodes of the graph) contains *m*-dimension vectors whose elements are integers (indices of Simplex bases) $u=(i_1, i_2, ..., i_m)$ for $1\leq i_j \leq m$, $j=1,2,...,m$.
- The distance between two different nodes $u_1=(i_1, i_2, ..., i_m)$ and $u_2=(k_1, k_2, ..., k_m)$ is $d \leq m$ if d is the number of elements in u_2 which are different from those of u_1. u_1 and u_2 are adjacent if the distance between them is d=1
- An $arc(u_1, u_2) \in U$ if and only if u_1 and u_2 are adjacent. The adjacent nodes του u_i constitute set $N(u_i)$



Graph (V,U)

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Reverse Simplex Method

- The method of reverse Simplex (Simplex Inverse) presented by Van de Panne (1975) who observed that each iteration of the Simplex algorithm is reversible replacing the role of the variable enters the basis of the role of the variable exiting.
- In other words, if in a base of Simplex variable x_j inserted in place of variable x_{Br}, during the execution of the reverse Simplex, x_{Br} is introduced in place of x_j. Following this process reduces the value of the objective function z by an amount equal to one in which increased when we performed z step of Simplex
- To build the hyperpolyedron of post-optimal soltions a new constraint is added in the LP: $z - Y = z^* - k$

  where Y is the deviation variable takes positive values or zero.
- During the first phase of the method all vertices of the hyperpolyedron that give Y>0 are calculated, and during the second phase all the vertices give Y = 0.

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A heuristic approach

- The number of vertices of the hyper-polyhedron of multiple optimal solutions is often too big and an exhaustive search requires huge computational effort. Heuristic methods offer a very good alternative to the problem of searching thousands of solutions which may not be of particular interest to the analyst.
- More often the analysts may be only interested in the information which will help him/her to examine the stability of the an optimal solution or the statistical variance of other solutions. For example according to Siskos (1984), the stability analysis may be performed by solving a linear programs (LP) having the following form:
- The coefficients of the new constraint in augmented optimal table of Simplex is the opposite values of the marginal values of the optimal solution table

$$\begin{cases} [\max] \text{ or } [\min] \psi = \sum_{j=1}^{n} p_j x_j \\ \text{s.t.} \\ \mathbf{Ax} \leq \mathbf{b} \\ \boxed{\mathbf{c}^t \mathbf{x} = z^*} \\ \mathbf{x} \geq 0 \end{cases}$$

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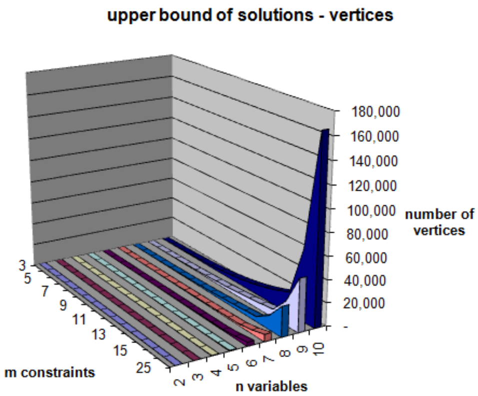
Number of multiple-optimal solutions

$$\bar{r} = \binom{n+m-\text{int}\left(\frac{n+1}{2}\right)}{m} + \binom{n+m-\text{int}\left(\frac{n+2}{2}\right)}{m}$$



	n		
m	**5**	**50**	**1000**
10	132	3.15E+08	5.94E+20
20	462	4.93E+12	1.16E+36
50	2652	7.01E+19	6.58E+71
1000	1003002	9.12E+49	#NUM!
5000	25015002	2.06E+67	#NUM!

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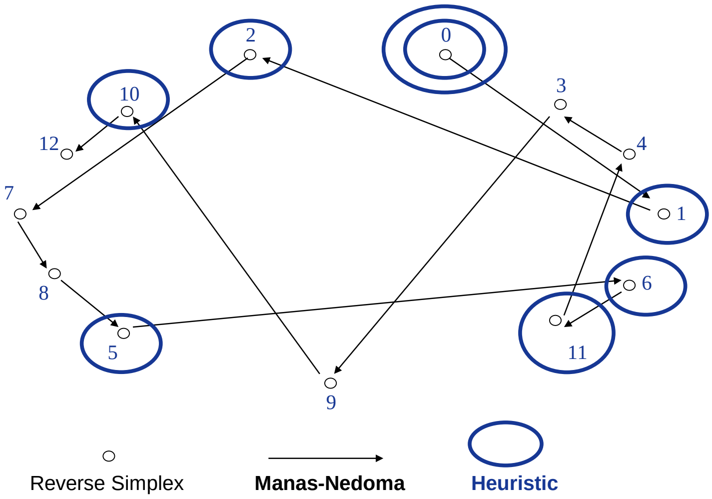
Method Copmarison



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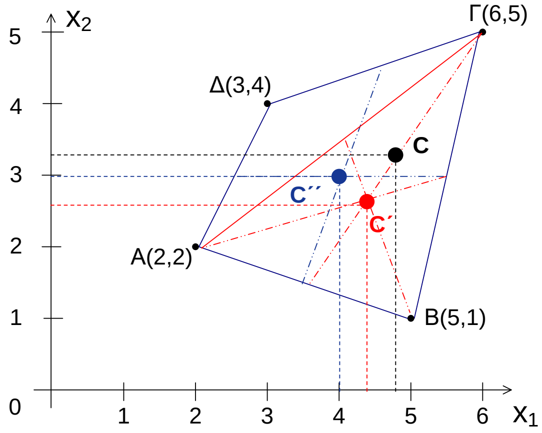
Analytic vs Heuristic



Heuristic

max x_1: Γ(6.00, 5.00)
max x_2: Γ(6.00, 5.00)
min x_1: A(2.00, 2.00)
min x_2: B(5.00, 1,00)

M.V.: C(4.75, 3.25)

Heuristic (without double)

max x_1: Γ(6.00, 5.00)
min x_1: A(2.00, 2.00)
min x_2: B(5.00, 1,00)

M.V.: C´(4.33, 2.67)

Analytic

A(2.00, 2.00)
B(5.00, 1,00)
Γ(6.00, 5.00)
Δ(3.00, 4.00)

M.V.: C´´(4.00, 3.00)

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Evaluation of UTA results (1)

The results produced by UTA methods could be evaluated according to the following measures:

- The minimised criterion *z* (sum of errors) taken as the indicator of dispersion of the observations
- The Spearman's rank correlation coefficient between the initial weak order R´ and the one produced (R) by the estimated model:

$$\rho_s = 1 - \frac{6\sum_{i=1}^{m}\delta_i^2}{m^3 - m} \quad \text{where} \quad \delta = R(i) - R'(i)$$

and in case of ties:

$$\rho_s = \frac{\sum_{i=1}^{m}\left[R(i) - \frac{m+1}{2}\right]\left[\left[R'(i) - \frac{m+1}{2}\right]\right]}{\sqrt{\sum_{i=1}^{m}\left[R(i) - \frac{m+1}{2}\right]^2 \sum_{i=1}^{m}\left[R'(i) - \frac{m+1}{2}\right]^2}}$$

$$= \frac{\sum_{i=1}^{m} R(i)\,R'(i) - m\left[\frac{m+1}{2}\right]^2}{\sqrt{\left[\sum_{i=1}^{m} R(i)^2 - m\left(\frac{m+1}{2}\right)^2\right]\left[\sum_{i=1}^{m} R'(i)^2 - m\left(\frac{m+1}{2}\right)^2\right]}}$$

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Evaluation of UTA results (2)

….

- The Kendall's tau between the initial weak order R´ and the one produced by the estimated model:

$$\tau = \frac{m_c - m_d}{\binom{m}{2}} = \frac{m_c - m_d}{m(m-1)/2}$$

where m_c the number of concordant pairs and m_d the number of discordant pairs.

and in case of ties:

$$\tau_b = \frac{m_c - m_d}{\sqrt{\left[m(m-1)/2 - \sum_{i=1}^{t} t_i(t_i-1)/2\right]\left[m(m-1)/2 - \sum_{i=1}^{u} u_i(u_i-1)/2\right]}}$$

where t_i is the number of observations tied at a particular rank of R´ and u_i is the number tied at a rank of R.

Average Stability Index as a measure of robustness

1. The robustness of the decision model depends on the post-optimality analysis results.
2. During the post-optimality stage, a number of solutions are produced for our UTA model following an analytical or heuristic approach.
3. The Average Stability Index (ASI) is the mean value of the normalized standard deviation of the estimated values:

$$ASI(i) = 1 - \frac{1}{n_{par}} \sum_{k=1}^{n_{par}} \frac{S_k}{Norm}$$

where S_k is the standard deviation of the estimated values of the parameters k of criterion i, n_{par} is the number of the parameters and *Norm* normalizing coefficient [0,1].

$$ASI(i) = 1 - \frac{1}{n_{par}} \frac{\sum_{k=1}^{n_{par}} \sqrt{\left(n_{sol}\left(\sum_{j=1}^{n_{sol}} \left(par_k^j\right)^2\right) - \left(\sum_{j=1}^{n_{sol}} par_k^j\right)^2\right)}}{\frac{n_{sol}}{n_{par}}\sqrt{\left(n_{par}-1\right)}}$$

where par_k^j is the value of parameter k of the *j-th post-optimal solution* and n_{sol} the total number of post-optimal solutions.

Average Stability Index as a measure of robustness

In UTA the number of unknown parameters per criterion *i* is (a_i – 1). In order to calculate the ASI(i) at a criterion level we use the distances between the marginal utility at each point of the scale, which are the monotonicity transformations of UTASTAR:

$$w(i)_k^j = u(i)_{k+1}^j - u(i)_k^j \geq 0 \quad \forall i = 1,2,\ldots,n_{cr}, \quad \forall j = 1,2,\ldots,n_{sol} \quad \text{και} \quad \forall k = 1,2,\ldots,a_i - 1$$

So, ASI could be written as: $$ASI(i) = 1 - \frac{\sum_{k=1}^{\alpha_i - 1} \sqrt{\left(n_{sol} \left(\sum_{j=1}^{n_{sol}} \left(w(i)_k^j \right)^2 \right) - \left(\sum_{j=1}^{n_{sol}} w(i)_k^j \right)^2 \right)}}{n_{sol} \sqrt{(\alpha_i - 2)}}$$

Global robustness measure: $$\mathrm{ASI} = \frac{1}{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{ASI(i)}$$

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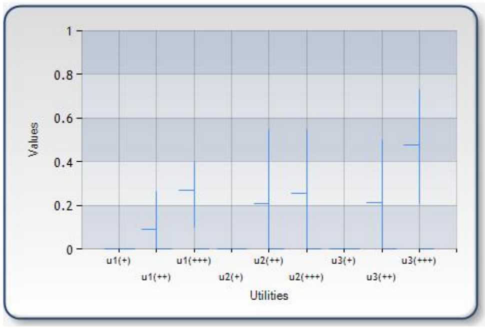
Other measures of robustness

Another measure is the distance between the maximum and the minimum value of a parameter while calculating the post-optimal solutions:

$$dis(k) = \max\left(par_k^j\right) - \min\left(par_k^j\right)$$

This measure could be easily provided in a graphical form.



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A S/W to deal with UTA robustness issues

An example in Stochastic UTA: Sales Director Selection

Candidates for the position are assessed by a committee that used a three-point quality scale: + (bad), + + (moderate), + + + (good).

Thus, for each criterion, the evaluation of each candidate *α* has the form of a probability distribution δ_i^{α}

	Personality			Intelligence			Experience		
Candidate	+	++	+++	+	++	+++	+	++	+++
A	0,3	0,4	0,3	0,2	0,6	0,2	0,3	0,6	0,1
B	0,1	0,1	0,8	0,3	0,5	0,2	0,7	0,2	0,1
C	0,5	0,2	0,3	0	0,2	0,8	0	0,7	0,3
D	0,1	0,3	0,6	0,4	0,4	0,2	0	0,1	0,9
E	0,4	0,4	0,2	0,3	0,5	0,2	0,4	0,4	0,2
F	0,2	0,5	0,3	0,4	0,5	0,1	0,5	0,4	0,1

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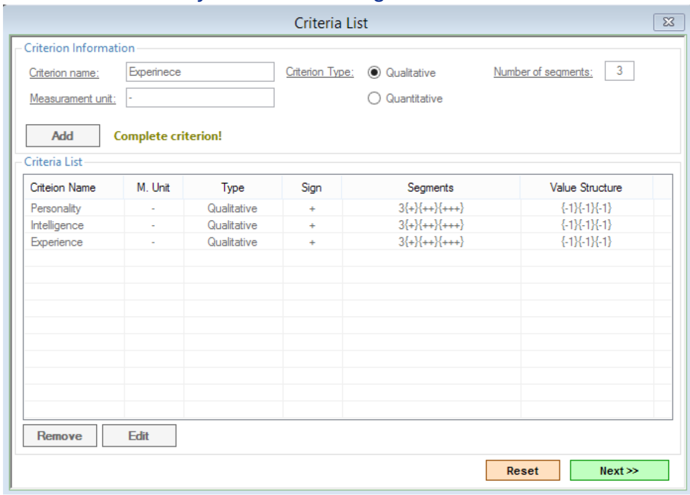
A S/W to deal with UTA robustness issues

Enter the data into the system concerning criteria and scales:



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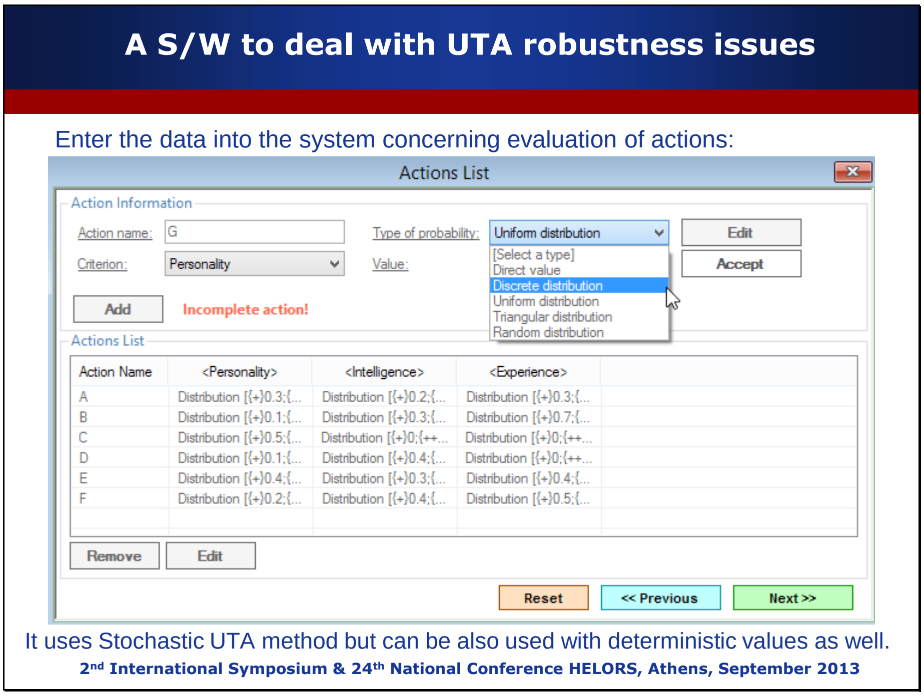
A S/W to deal with UTA robustness issues
Enter the data into the system concerning evaluation of actions:
Actions List
Action Information
Action name: G
Type of probability: Uniform distribution
Edit
Accept
Criterion: Personality
Value:
[Select a type]
Direct value
Discrete distribution
Uniform distribution
Triangular distribution
Random distribution
Add
Incomplete action!
Actions List
Action Name <Personality> <Intelligence> <Experience>
A Distribution [{+}0.3;{... Distribution [{+}0.2;{... Distribution [{+}0.3;{...
B Distribution [{+}0.1;{... Distribution [{+}0.3;{... Distribution [{+}0.7;{...
C Distribution [{+}0.5;{... Distribution [{+}0;{++... Distribution [{+}0;{++...
D Distribution [{+}0.1;{... Distribution [{+}0.4;{... Distribution [{+}0;{++...
E Distribution [{+}0.4;{... Distribution [{+}0.3;{... Distribution [{+}0.4;{...
F Distribution [{+}0.2;{... Distribution [{+}0.4;{... Distribution [{+}0.5;{...
Remove
Edit
Reset
<< Previous
Next >>
It uses Stochastic UTA method but can be also used with deterministic values as well.
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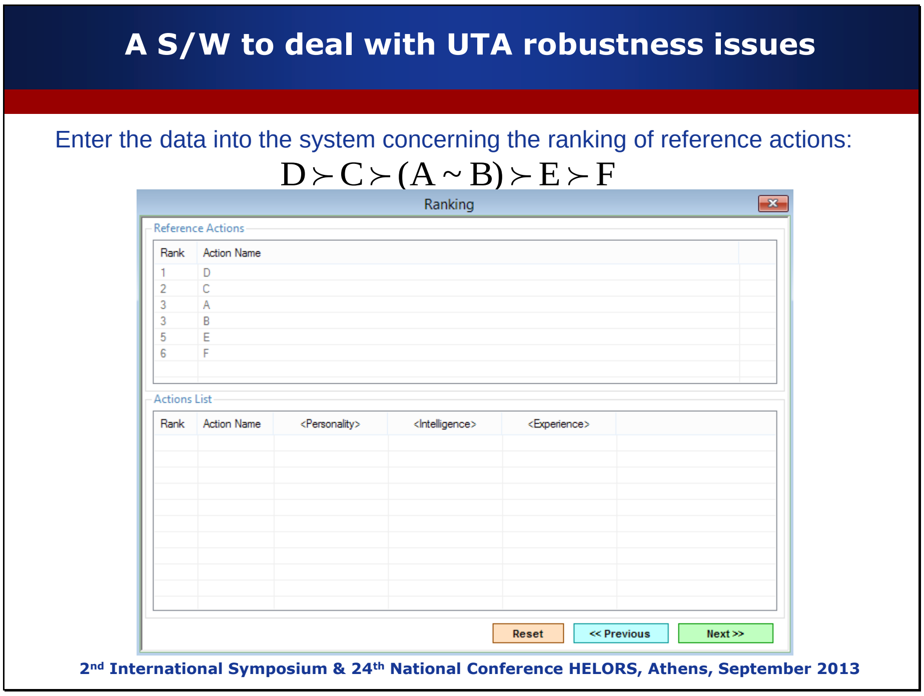
A S/W to deal with UTA robustness issues
Enter the data into the system concerning the ranking of reference actions:
D ≻ C ≻ (A ~ B) ≻ E ≻ F
Ranking
Reference Actions
Rank Action Name
1 D
2 C
3 A
3 B
5 E
6 F
Actions List
Rank Action Name <Personality> <Intelligence> <Experience>
Reset
<< Previous
Next >>
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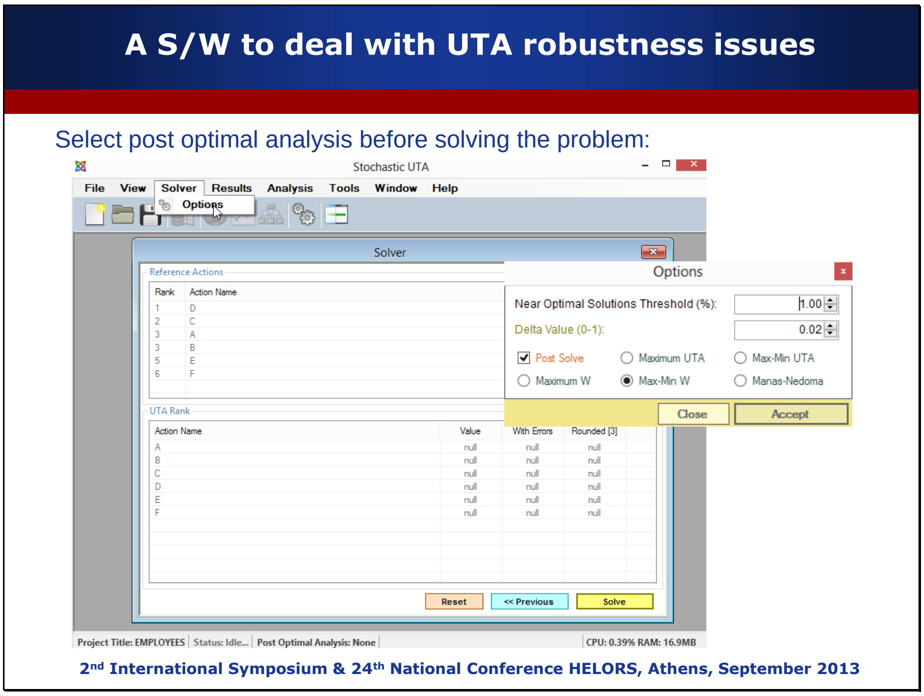
A S/W to deal with UTA robustness issues
Select post optimal analysis before solving the problem:
Stochastic UTA
File View Solver Results Analysis Tools Window Help
Options
Solver
Options
Near Optimal Solutions Threshold (%): 1.00
Delta Value (0-1): 0.02
Post Solve
Maximum UTA
Max-Min UTA
Maximum W
Max-Min W
Manas-Nedoma
Close
Accept
Reset
<< Previous
Solve
Project Title: EMPLOYEES Status: Idle... Post Optimal Analysis: None CPU: 0.39% RAM: 16.9MB
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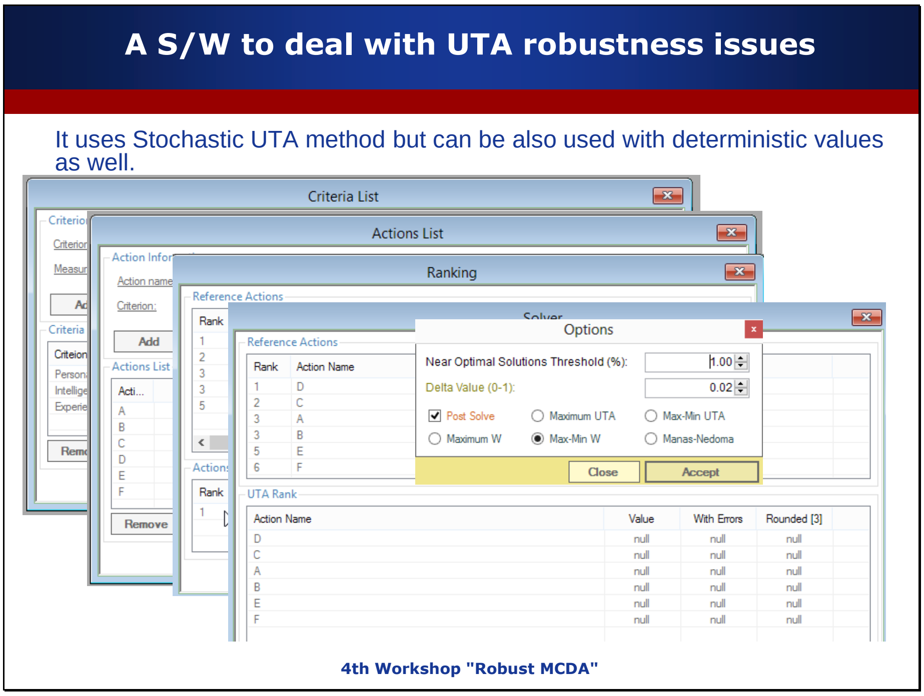
A S/W to deal with UTA robustness issues
It uses Stochastic UTA method but can be also used with deterministic values as well.
Criteria List
Actions List
Ranking
Options
Near Optimal Solutions Threshold (%): 1.00
Delta Value (0-1): 0.02
Post Solve
Maximum UTA
Max-Min UTA
Maximum W
Max-Min W
Manas-Nedoma
Close
Accept
UTA Rank
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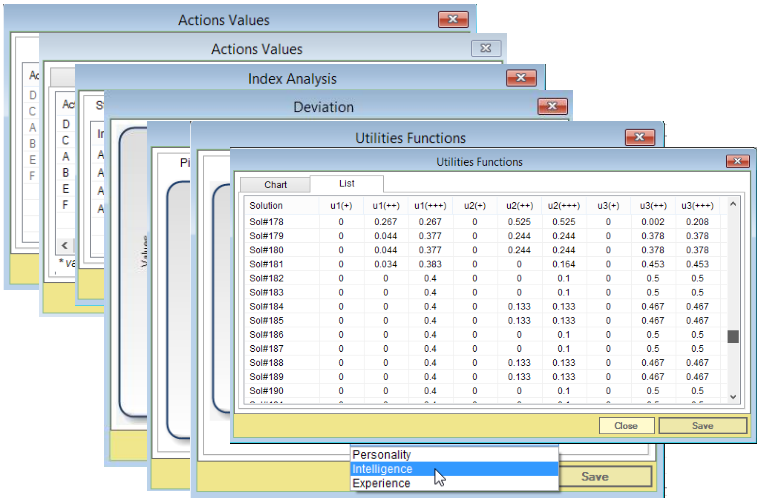
A S/W to deal with UTA robustness issues

It provides all results of post optimal solutions and measures of robustness.



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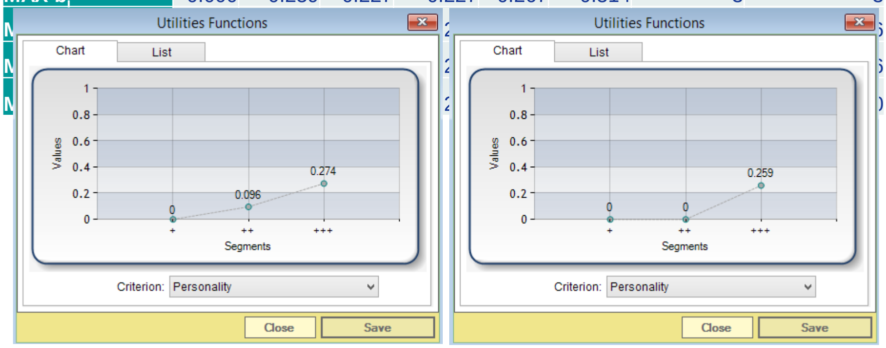
Results from comparing analytical vs. heuristics

Different methods, different barycentres – The correct one produced by the analytical approach (Manas-Nedoma):

Post Optimal Method	$u_1(++)$	$u_1(+++)$	$u_2(++)$	$u_2(+++)$	$u_3(++)$	$u_3(+++)$	# Solutions (vertices)	set of utilities' values
Manas -Nedoma	0.096	0.274	0.211	0.295	0.218	0.430	259	21
MAX b_i	0.000	0.259	0.227	0.227	0.267	0.514	3	3



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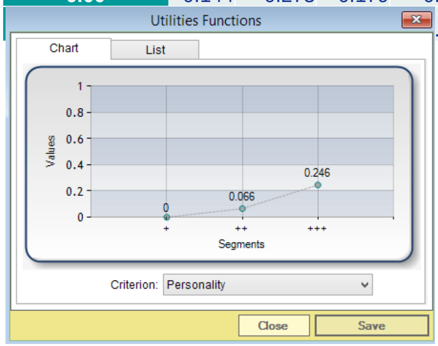
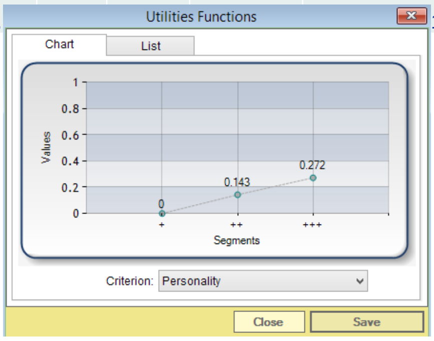
Results from comparing analytical vs. heuristics

Different values for δ, different barycentres using the same method (Manas-Nedoma):

δ's values	u_1(++)	u_1(+++)	u_2(++)	u_2(+++)	u_3(++)	u_3(+++)	# Solutions (vertices)	set of utilities' values
0.04	0.066	0.245	0.252	0.323	0.194	0.432	142	11
0.00	0.144	0.273	0.179	0.281	0.189	0.446	259	18





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Results from comparing analytical vs. heuristics

Different methods, different ASI – The correct one produced by the analytical approach (Manas-Nedoma):

Post Optimal Method	ASI(b1)	ASI(b2)	ASI(b3)	Total ASI
Manas -Nedoma	78.48%	59.67%	67.19%	68.45%
MAX b_i	88.11%	53.41%	64.10%	68.54%
MAX - MIN b_i	78.55%	50.93%	62.55%	64.01%
MAX $u(g_i^j)$	77.79%	54.59%	63.28%	65.22%
MAX-MIN $u(g_i^j)$	77.78%	55.27%	65.61%	66.22%

Different values for δ, different ASI using the same method (Manas-Nedoma):

δ's values	ASI(b1)	ASI(b2)	ASI(b3)	Total
0.04	86.82%	59.01%	70.10%	71.98%
0.00	74.04%	57.96%	65.62%	65.87%
0.02	78.48%	59.67%	67.19%	68.45%

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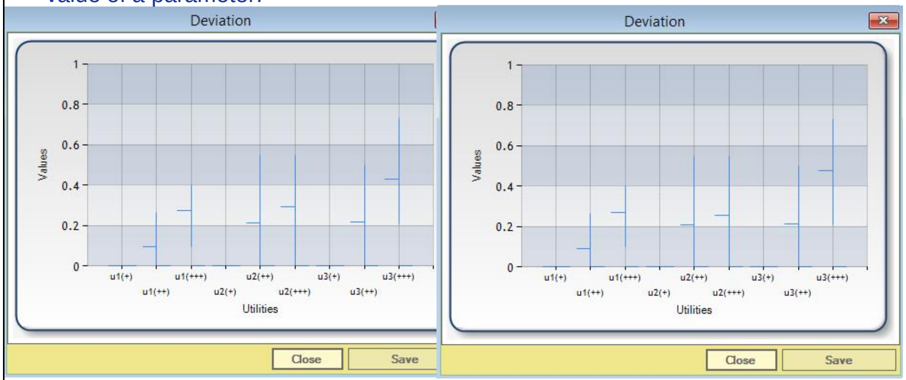
Results from comparing analytical vs. heuristics

Different methods, different distance between the maximum and the minimum value of a parameter:



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Conclusions

1

Manas-Nedoma algorithm which guarantees the search of all basic feasible solutions of a hyper-polyhedron, is efficient in terms of computational time for most of UTA problems given the dimensions of such models.

2

Average Stability Index (ASI) is an easy to understand robustness measure for Analysts and Decisions Makers.

3

The representation of Weight Variations with visualization tools provides important information concerning the robustness of the model.

4th Workshop "Robust MCDA"

Future Research

1

More visual tools shall be created in order to increase the perception of the actual robustness of an inferred model, for both the Analyst and the DM.

2

Provide a well structured framework to support a feedback procedure though which the robustness of the model could be improved.

3

We are finalising some additional tools in our software for supporting the analyst in choosing better set of parameters (δ, ε) for each model in order to improve robustness measures.

4th Workshop "Robust MCDA"

Nikos Tsotsolas (ntsotsol@unipi.gr)

4o Επιστημονικό Workshop

Robust MCDA

Enriching interactivity of Disaggregation - Aggregation Approaches through the exploitation of Robustness Analysis results

Athanasios Spyridakos, Yannis Siskos, Denis Yannacopoulos and Nikos Tsotsolas

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Ευρωπαϊκή Ένωση
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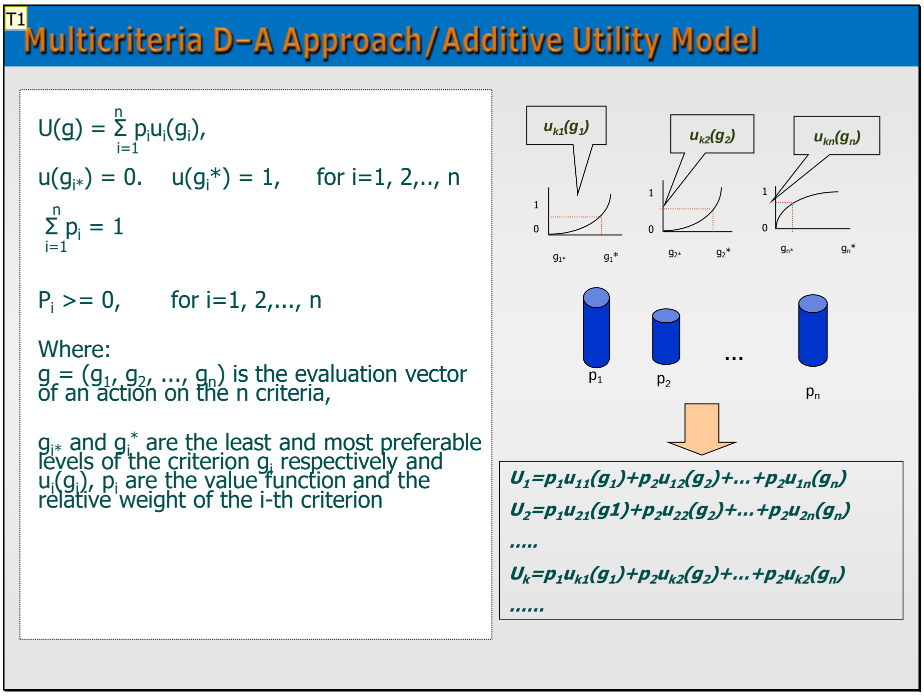
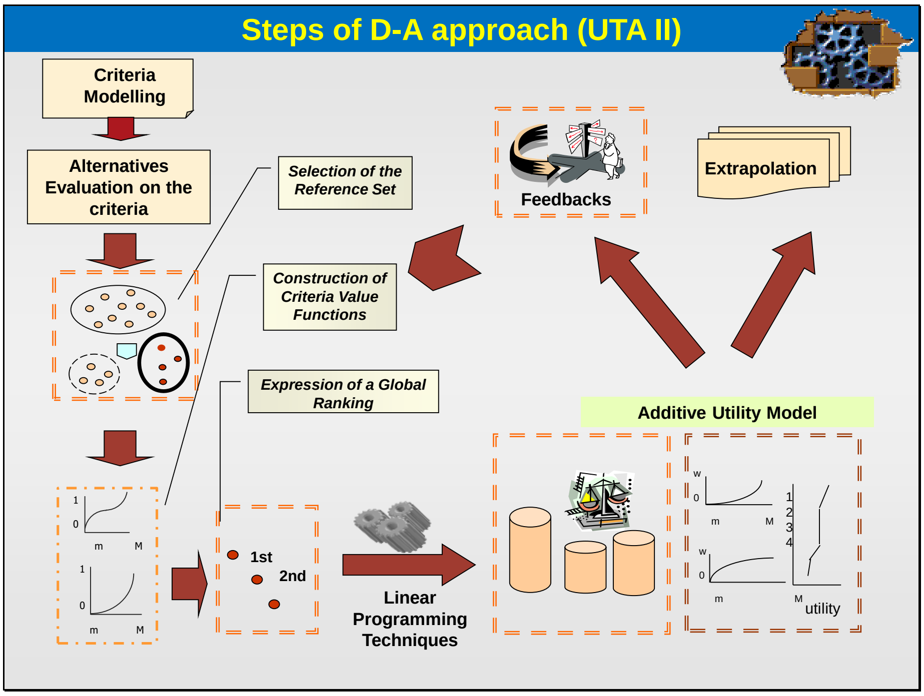
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης
ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Content

- **Robustness Analysis of Preference Models in Disaggregation- Aggregation Approach**
- **Exploitation of the Robustness Analysis and new interactive feedbacks**
- **Conclusions – Further Development**


T1
Multicriteria D-A Approach/Additive Utility Model
U(g) = Σ_{i=1}^{n} p_i u_i(g_i),
u(g_{i*}) = 0. u(g_i*) = 1, for i=1, 2,.., n
Σ_{i=1}^{n} p_i = 1
P_i >= 0, for i=1, 2,..., n
Where:
g = (g_1, g_2, ..., g_n) is the evaluation vector of an action on the n criteria,
g_{i*} and g_i* are the least and most preferable levels of the criterion g_i respectively and u_i(g_i), p_i are the value function and the relative weight of the i-th criterion
u_{k1}(g_1)
u_{k2}(g_2)
u_{kn}(g_n)
p_1
p_2
...
p_n
U_1=p_1u_{11}(g_1)+p_2u_{12}(g_2)+...+p_2u_{1n}(g_n)
U_2=p_1u_{21}(g1)+p_2u_{22}(g_2)+...+p_2u_{2n}(g_n)
.....
U_k=p_1u_{k1}(g_1)+p_2u_{k2}(g_2)+...+p_2u_{k2}(g_n)
......


Steps of D-A approach (UTA II)
Criteria Modelling
Alternatives Evaluation on the criteria
Selection of the Reference Set
Construction of Criteria Value Functions
Expression of a Global Ranking
Feedbacks
Extrapolation
Additive Utility Model
1st
2nd
Linear Programming Techniques
utility

Linear Programming Techniques (UTA II)

Alternatives a_i are re-arranged so as $a_i P a_{i+1}$ or $a_i \, I \, a_{i+1}$.(see Jacquet-Lagreze and Siskos, 1982 or Siskos, 1980).

$$[\min]F, \quad F = \sum_{i=1}^{k}(\sigma^+(a_i) + \sigma^-(a_i))$$

s.t.

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] > \delta \quad \text{if } a_m \, P \, a_{m+1}$$

or

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] = 0 \quad \text{if } a_m \, I \, a_{m+1}$$

for $m=1, 2, \ldots, k-1$

$$\sum_{i=1}^{n} p_i = 1$$

$p_i \geq 0$, for $i=1, 2, \ldots, n$

$\sigma^+(a_j) \geq 0$, $\sigma^-(a_j) \geq 0$, for $j = 1,2, \ldots, k$

where δ a small positive number; $g_i(a_m)$ the evaluation of the a_m action on the i-th criterion and $u_i[g_i(a_m)]$ the corresponding marginal utility; and $\sigma^+(a_j)$, $\sigma^-(a_j)$ the over(under)estimation errors concerning the j-th of the k actions, sorted in the ranking order.

Solution of L.P.

The Linear Programme results in:

A. Only one solution (Robust) There is only one vector of the weights

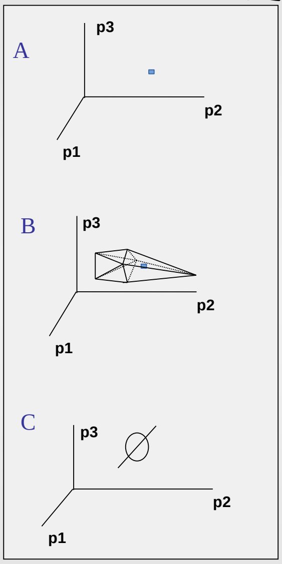
B. Infinite Solutions (Non Robust)

C. No Solutions, often in cases with extremely low structure.

Question?

In non robust cases which could be the vector of weights to work with ?

MINORA and MIIDAS systems (Siskos et al, 1993, 1999) utilise Post Optimal Analysis. Solutions are estimated by maximising The weight of every criterion. The mean solution (barycenter) constitute the working vector of weights



Post Optimal Analysis

Post Optimal Analysis. (see Jacquet-Lagreze and Siskos, 1982 or Siskos, 1980). The n-LP programmes are solved:

$\text{Max}(P_i),\ i=1,2,\ldots,n$

s.t.

$F = \sum_{i=1}^{k} (\sigma^+(a_i) + \sigma^-(a_i))$, **F the estimated f(*)**

$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] > \delta$ if $a_m\ P\ a_{m+1}$

or $\geq$

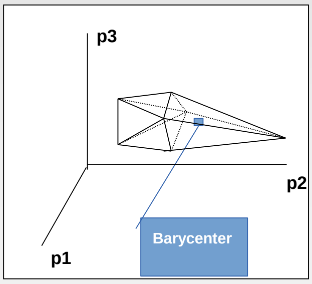
$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] = 0$ if $a_m\ I\ a_{m+1}$

for $m=1, 2, \ldots, k-1$

$\sum_{i=1}^{n} p_i = 1$

$p_i \geq 0$, for $i=1, 2, \ldots, n$

$\sigma^+(a_j) \geq 0$, $\sigma^-(a_j) \geq 0$, for $j = 1,2, \ldots, k$



where δ a small positive number; $g_i(a_m)$ the evaluation of the a_m action on the i-th criterion and $u_i[g_i(a_m)]$ the corresponding marginal utility; and $\sigma^+(a_j)$, $\sigma^-(a_j)$ the over(under)estimation errors concerning the j-th of the k actions, sorted in the ranking order.

Robustness Analysis

Low robust solutions are the outcome of:

- a kind of uncertainty about the criteria weights
- the real thoughts of the DMs
- difficulties to uncover DMs' real preferences
- Inadequacy of the problem formulation and DM's expressed preferences

The proposed Robustness Analysis of Preference Models aims to:

a) Explain the low robustness and increase the knowledge about the DMs' preference structures

b) Determine actions (Feedbacks) to be taken in order to decrease the level of low Robustness

Available Data for Robust Analysis

Problem Statement and Preferences

- *Alternative Actions A={a_i, i=1,2, ,n}*
- *Criteria: G = {g_j, j=1,2,…k}*
- *Alt. Actions evaluation on the criteria: g_{ij}, i=1,2,..,n, j=1,2, ,k*
- *Reference Set A'={a'_i, i=1,2, ,n} Ranking of the Reference Set: R(a'_i), a'_i є A'*

Preference Model

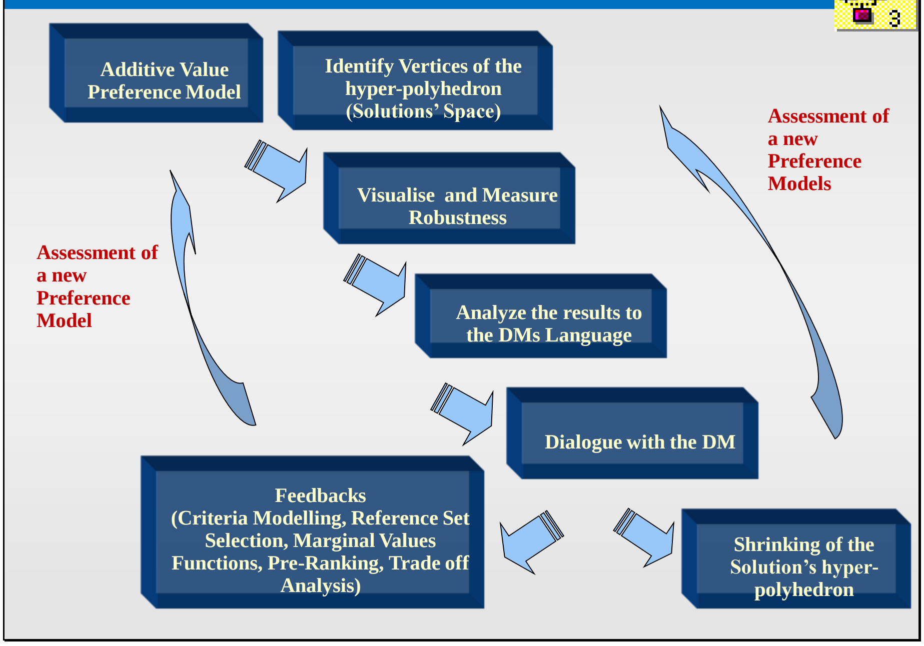
- Marginal Value Functions $u_j=u_j(g_j)$, j=1,2,…k., $u_j(g_{j*})=0$ and $uj(g_j^*)=1$
- Criteria Weights: p_j, j=1,2,…k
- Maximum and Minimum Values of Criteria Weights p_{maxj}, p_{minj}, j=1,2,…k
- Over and Under-estimation errors σ_i+, σ_i-, όπου i=1,2,..,n
- The Vertices vector of the hyper-polyedron (Manas-Nedoma)

Exploitation of Assessed Preference Model

- Alt. Actions' marginal values on the criteria $u_{ij} = u_i(g_j)$
- Global Values:

$$U(\underline{g}) = \sum_{i=1}^{n} p_i u_i(g_i)\ ,\ i=1..n,\ j=1..k$$

Steps of the proposed approach (Feedbacks)



Indices to be used

A. Minimum and maximum values of the criteria weights (Post Optimal Analysis)

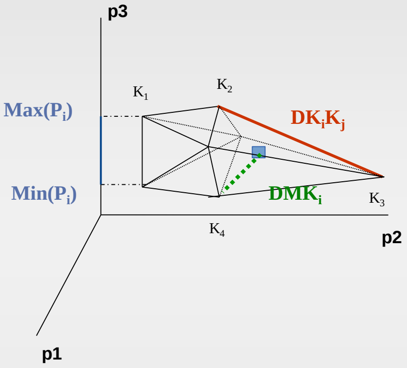
$\mu_i = (Max(P_{ij}) - Min(P_{ij}))$, $i=1,2..n$ $j=1,2 \ldots P$, P_{ij} weight of criterion i for the vertice j and n the number of criteria and m the number of vertices

B. The Euclidean Distances of the Vertices of the hyper-polyhedron.

$d_{ij} = DK_iK_j$ $\iota,j=1,2,..m$ και $i \neq j$

C. The Euclidean Distance of the hyper-polyhedron vertices from the barycenter

DMK_i, $\iota=1,2,..\rho$



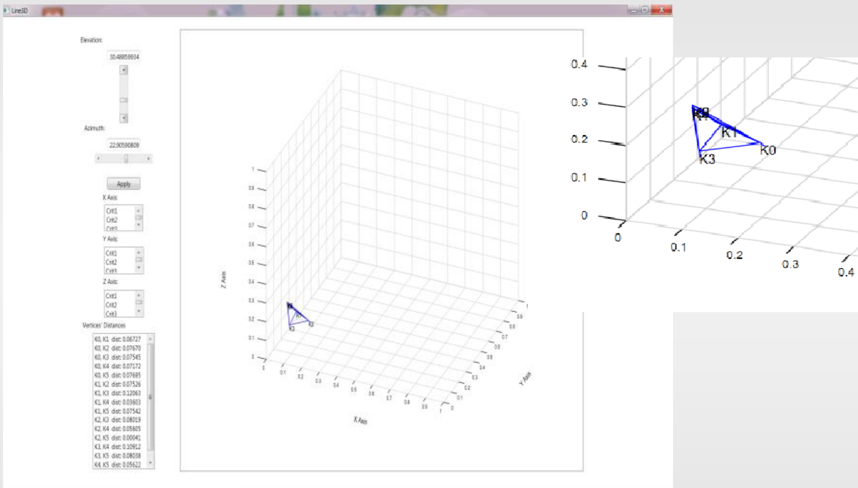
D. The ASI Index (n= number of criteria and m number of vertices) (Grigoroudis & Siskos)

$$s = 1 - \frac{1}{n}\sqrt{\frac{m\sum_{1=1}^{n}\sum_{j=1}^{m}p_{ij}^2 - (\sum_{i=1}^{n}\sum_{j=1}^{m}p_{ij})^2}{\frac{m\sqrt{m-1}}{n}}}$$

The RAVI Subsystem (Robustness Analysis through Visual and Interactive Approaches)

- Supports the Visualisation of n-dimensional spaces in 3d and 2d form
- Includes Links with MINORA and MIIDAS systems
- Supports Interactive feedbacks for the scrutiny of the hyper-polyhedra
- Aims:
  - Component of MINORA and MIIDAS systems.
  - Simple and easy way to present the Robustness of the assessed preference structures.
  - Acquire knowledge about preference models' structures and support the decision making.
  - Lead to more robust preference models through intervention on the preference models utilising addition preference information.
- Technology (.NET Platform, Windows Presentation FrameWork, Visual C# and Libraries for Linear Algebra and 3D graphs)

Screen Layout of RAVI – 3D Graphs



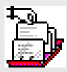
Selection of 3 criteria. Projection using Azimuth and Elevation for the position of the Observer.

Robustness Analysis

- Visualisation of the Preference Models – Utilising 3d and 2d graphs for n –Dimentional Data
- Dive into the Assessed Preference Models through tomographic approaches
- Examine the consequences on the preference models robustness for interventions
- Examine the capability to estimate a more robust preference models
- Estimate a more robust or a robust preference model.

Crucial :

- The participation of the Decision Maker
- Focused and limited interventions.



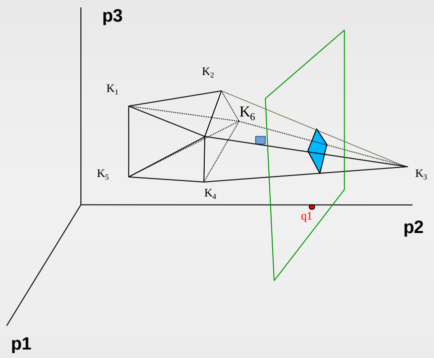
Case Study –Robustness Analysis and Feedbacks

Three new modules for Robustness Analysis

Aim: The exploitation of the Robustness analysis so as to support decisions

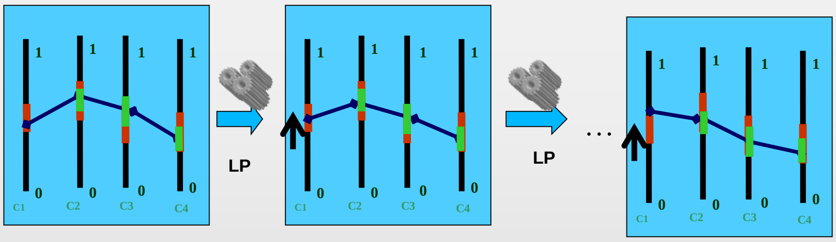
- Tomographical technique
- Shrinking the Hyper-polyhedron
- Prioritizations on the criteria

1. Tomographical Technique



Tomographical Approach

- For every criterion i
- Starting with the P_{imin} value with a step (ex. 0.01) and until P_{imax} estimate the ranges of weights of the other criteria solving the Linear Programmes of Post Optimal Analysis including the new condition.
- Present the criteria weights in a parallel coordination graph in a controlled continuous base.
- Outcomes: Visualisation and Identification of the impacts on the criteria weights for changes on the weight of the criterion i.



Modified Linear Programme

The 2n- linear programs are solved

Max Pi, Min Pi i=1,2,…, n

Subject to

$$F = \sum_{i=1}^{k}(\sigma^+(a_i) + \sigma^-(a_i))$$

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] \underset{\geq}{>} \delta \quad \text{if } a_m \text{ P } a_{m+1}$$

or

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] = 0 \quad \text{if } a_m \text{ I } a_{m+1}$$

for m=1, 2, ..., k-1

$$\sum_{i=1}^{n} p_i = 1$$

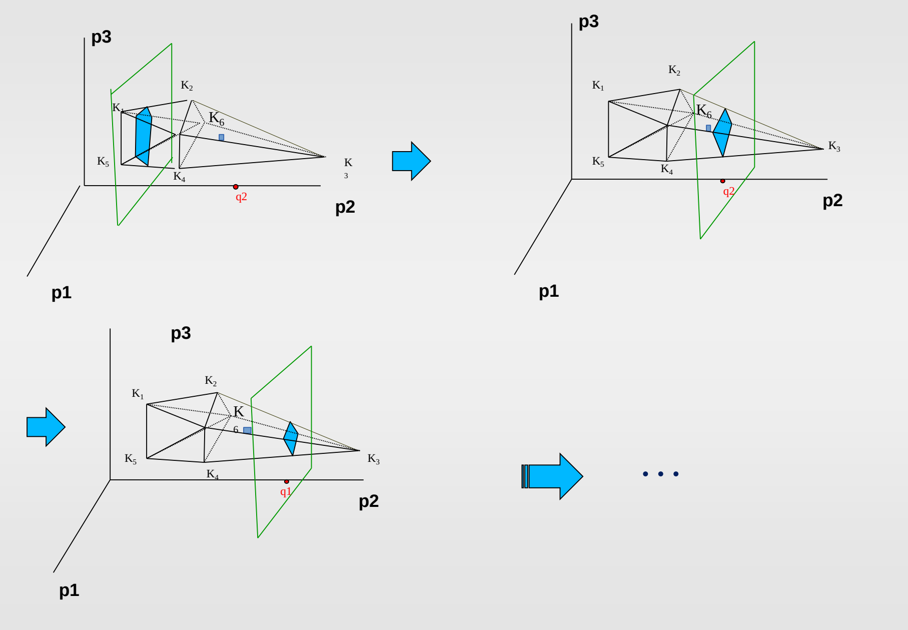
$p_i \geq 0$, for i=1, 2,..., n

$\sigma^+(a_j) \geq 0$, $\sigma^-(a_j) \geq 0$, for j = 1,2, ..., k

$P_i = q$ ($q = Min(p_i) + r*step$), r=1,2, .. and $q \leq Max(p_i)$)

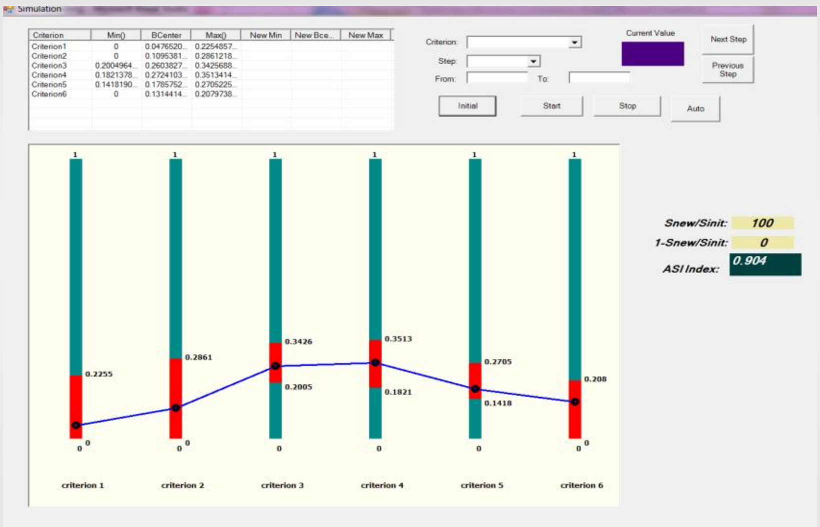
where δ a small positive number; $g_i(a_m)$ the evaluation of the a_m action on the i-th criterion and $u_i[g_i(a_m)]$ the corresponding marginal utility; and $\sigma^+(a_j)$, $\sigma^-(a_j)$ the over(under)estimation errors concerning the j-th of the k actions, sorted in the ranking order and r_{iI}, r_{i2} are the minimum and maximum values of the criteria weights expressed by the DM.

Tomographies of the Hyper-polyhedron



Tomographical Approach - Example

- **Initial Preference Model – Weights of the Criteria (ASI Index 0.904)**

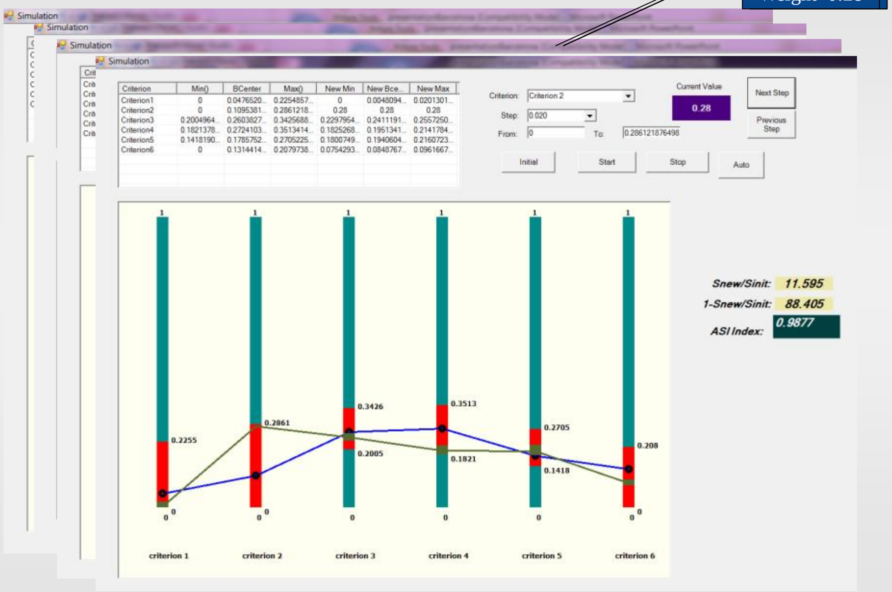


Criterion	Min()	BCenter	Max()	New Min	New Bce...	New Max
Criterion1	0	0.0476520...	0.2254857...			
Criterion2	0	0.1095381...	0.2861218...			
Criterion3	0.2004964...	0.2603827...	0.3425688...			
Criterion4	0.1821378...	0.2724103...	0.3513414...			
Criterion5	0.1418190...	0.1785752...	0.2705225...			
Criterion6	0	0.1314414...	0.2079738...			

Tomographical Approach - Example

- Iterations (criterion 2, step 0.02)

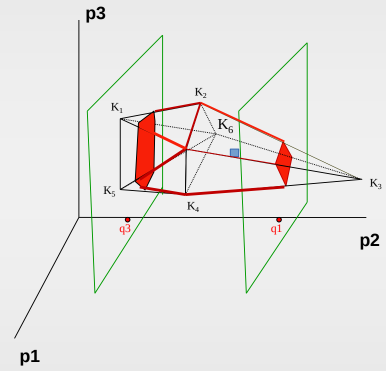
Criterion 2 – Weight 0.28



Tomography - Utilization

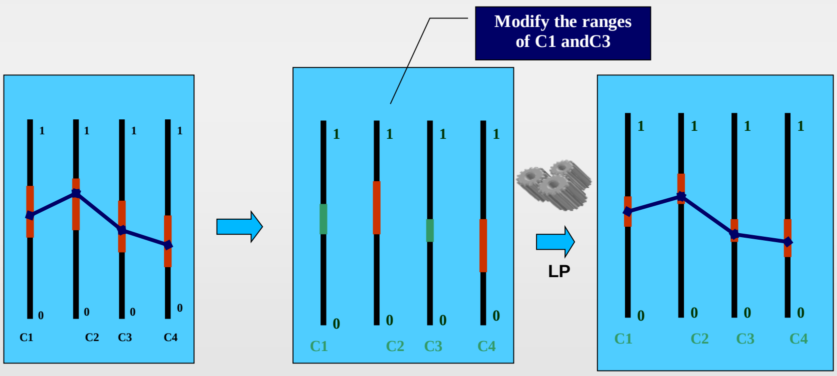
- Provides a way to explore the Robustness into the estimated hyper-polyhedron
- Pictures the levels of robustness for every criterion and determine conditions under which total robustness can achieved.
- Support the identification of the reasons why robustness is presented into the estimated preference model. (ex. Focus on the expressed pre-ranking)
- The produced n-1 dimensions hyper-polyhedra gives a picture of the robustness providing a flexible way to support new dialogues with the DMs such as:
  - Which are the ranges of the criteria weights that can be considered acceptable by the DMs and leads to a higher robustness for the preference mode?
  - Which are the criteria that the DM agree or not with the weights estimated?
- Identify areas of the estimated hyper-polyhedron with high or low Robustness and examine the DMs attitudes

2. Shrinking Weights' Tolerance



Shrinking Weights' Tolerance

- Establish focused dialogues with the DM in order to identify indirectly more strict ranges of the criteria weights (not all of them).
- Development of a new linear program embedding the new conditions.
- A new preference model can be assessed satisfying the new ranges of the criteria weights. It is expected to increase the preference model robustness.



Shrinking Weights' Tolerance- Modified Linear Programme

The 2n- linear programs are solved

Max Pi, Min Pi i=1,2,…, n

Subject to

$$F = \sum_{i=1}^{k}(\sigma^{+}(a_j) + \sigma^{-}(a_j))$$

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^{+}(a_m) - \sigma^{-}(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^{+}(a_{m+1}) - \sigma^{-}(a_{m+1})] \underset{\geq}{>} \delta \quad \text{if } a_m \text{ P } a_{m+1}$$

or

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^{+}(a_m) - \sigma^{-}(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^{+}(a_{m+1}) - \sigma^{-}(a_{m+1})] = 0 \quad \text{if } a_m \text{ I } a_{m+1}$$

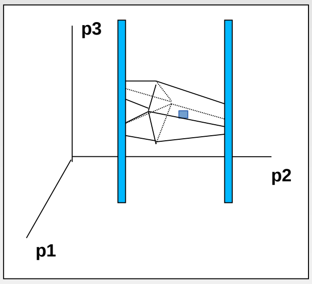
for m=1, 2, ..., k-1

$$\sum_{i=1}^{n} p_i = 1$$

$p_i \geq 0$, for i=1, 2,..., n

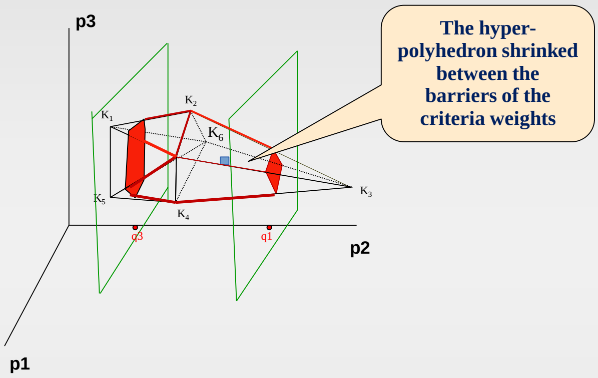
$\sigma^{+}(a_j) \geq 0$, $\sigma^{-}(a_j) \geq 0$, for j = 1,2, ..., k

$p_i \geq r_{i2}$ $p_i \leq r_{i1}$ for some of the criteria



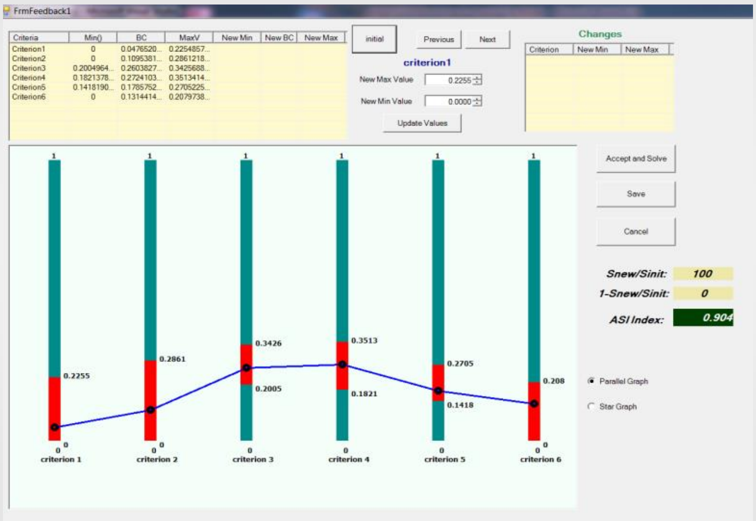
where δ a small positive number; $g_i(a_m)$ the evaluation of the a_m action on the i-th criterion and $u_i[g_i(a_m)]$ the corresponding marginal utility; and $\sigma^{+}(a_j)$, $\sigma^{-}(a_j)$ the over(under)estimation errors concerning the j-th of the k actions, sorted in the ranking order and r_{i1}, r_{i2} are the minimum and maximum values of the criteria weights expressed by the DM.

Shrinking Weights' Tolerance



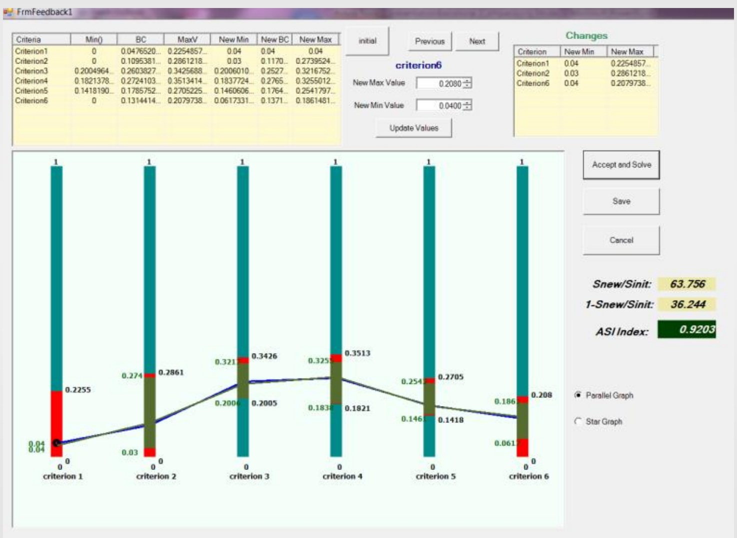
Shrinking Weights Tolerance- Example

- **Initial Preference Model – Weights of the Criteria (ASI Index 0.904)**



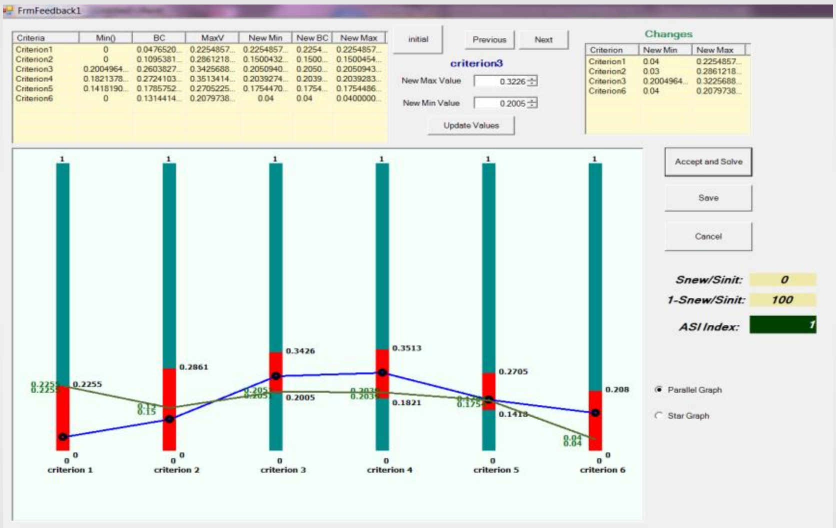
Shrinking Weights Tolerance- Example

- **An Obvious feedback is to identify new minimum values for the weights for criteria with 0 minimum weights**



Shrinking Weights Tolerance- Example

- **Giving new minimum weight for criterion 3 we have a robust model**



Shrinking Weights - Utilisation

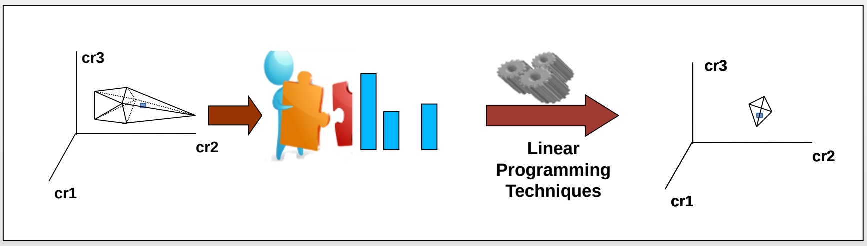
- Robustness Analysis can support the dialogues with the DMs in order to acquire more information concerning his/her preferences.
- Extreme situations (e.x. Zero or very high or very low criteria weights) can be the starting point for dialogues to extract additional preference information by the DM
- Increasing Robustness of the Preference Models can lead to :
  - A better apprehension of the Problem Statement and Preference Structures
  - The realization of their preference attitudes (by the DMs)
- Remaining Low Robustness can lead to:
  - Identification of the reasons why
  - New feedbacks concerning the Problem Formulation, Alternative Actions evaluation on criteria, pre-ranking etc.
- All the Above for the Objective: Support the Decision Making.

3. Criteria Prioritisation

Criteria Prioritization

- Establish focused dialogues with the DM in order to extract information about the priorities of the criteria triggered by the analysis of the assessed preference model and the Robustness Analysis.
- (For example: a) Utilize 3 or more alternatives (real or virtual) in order to identify more detailed information for his/her preferences into selected criteria
- b) Insertion of one or more alternatives in the reference set which are representative of a specified subspace of the decision space

- Construction of a new linear program embedding the above information and estimation of a more robust preference model through Post Optimal Analysis or Manas Nedoma Algorithm.



Dialogue - Example

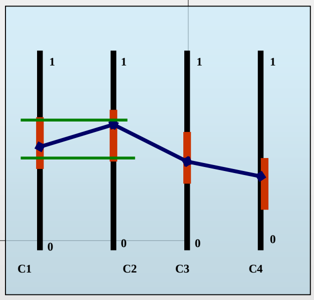
Using virtual or real alternative actions we can acquire additional preferences' data from DM.

For 3 criteria with 3 alternative actions.

Alternative Actions	Criteria		
	Cr1	Cr2	Cr3
alt1	3	3	4
alt2	2	4	4
alt3	4	3	3

Condition:

The intersection of [MinCr1, MaxCr1] and [MinCr2, MaxCr2] is not null



Examine Cr1 with Cr2 and Cr3

Alt1 P Alt2

Alt3 P Alt1

Enriches the Linear Program and can lead to more robust solution

New (Post Analysis) Linear Programme

The 2n- linear programs are solved

Mas Pi, Min Pi i=1,2,…, n,

Subject to

$$F = \sum_{i=1}^{k}(\sigma^+(a_j) + \sigma^-(a_j))$$

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] > \delta \quad \text{if } a_m \text{ P } a_{m+1}$$

or $\geq$

$$\sum_{i=1}^{n} p_i u_i[g_i(a_m)] + \sigma^+(a_m) - \sigma^-(a_m) - [\sum_{i=1}^{n} p_i u_i[g_i(a_{m+1})] + \sigma^+(a_{m+1}) - \sigma^-(a_{m+1})] = 0 \quad \text{if } a_m \text{ I } a_{m+1}$$

for m=1 , 2, ..., k-1

$$\sum_{i=1}^{n} p_i u_i[g_i(alt1)] + \sigma^+(alt1) - \sigma^-(alt1) - [\sum_{i=1}^{n} p_i u_i[g_i(alt2)] + \sigma^+(alt2) - \sigma^-(alt2)] > \delta$$

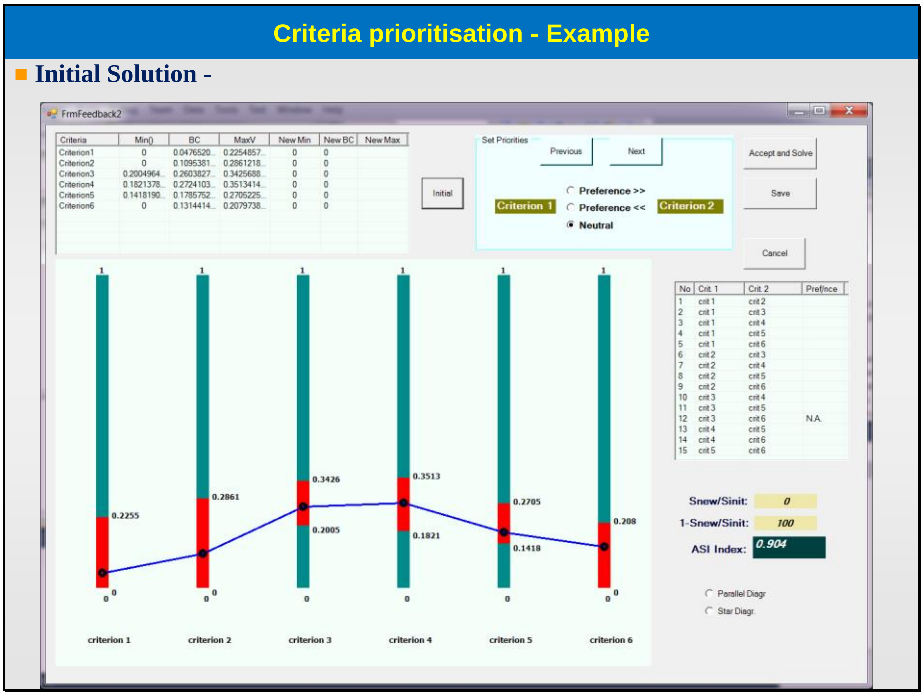
Or $p_i > p_j$, I,j=1,2,..n and $i \neq j$

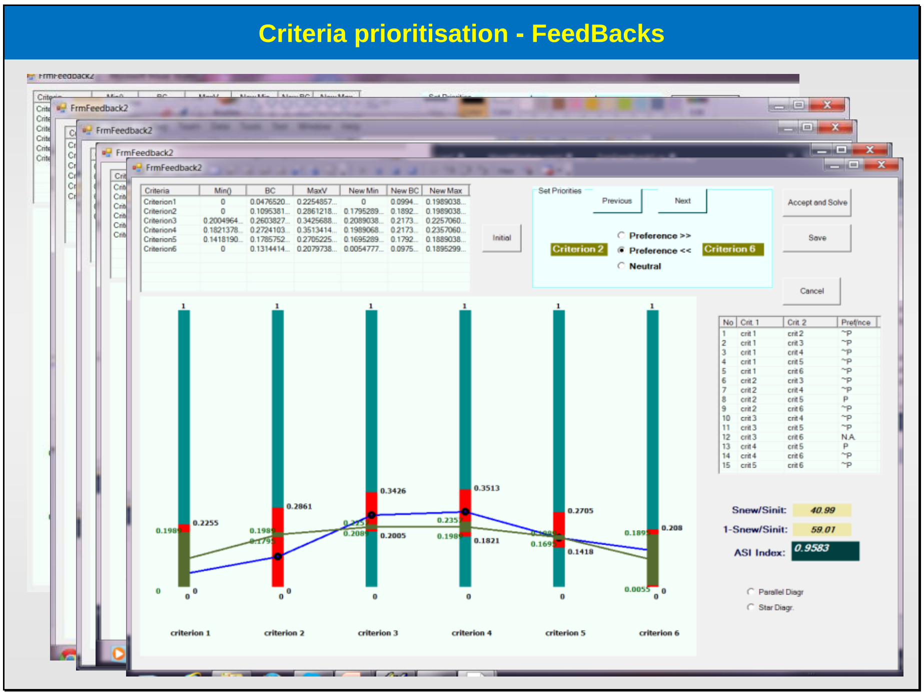
$$\sum_{i=1}^{n} p_i = 1$$

$p_i \geq 0$, for i=1, 2,..., n

$\sigma^+(a_j) >= 0$, $\sigma^-(a_j) >= 0$, for j = 1,2, ..., k

where δ a small positive number; $g_i(a_m)$ the evaluation of the a_m action on the i-th criterion and $u_i[g_i(a_m)]$ the corresponding marginal utility; and $\sigma^+(a_j)$, $\sigma^-(a_j)$ the over(under)estimation errors concerning the j-th of the k actions, sorted in the ranking order.


Criteria prioritisation - Example
Initial Solution -
FrmFeedback2
Initial
Set Priorities
Previous
Next
Criterion 1
Preference >>
Preference <<
Neutral
Criterion 2
Accept and Solve
Save
Cancel
Snew/Sinit:
0
1-Snew/Sinit:
100
ASI Index:
0.904
Parallel Diagr.
Star Diagr.
criterion 1
criterion 2
criterion 3
criterion 4
criterion 5
criterion 6


Criteria prioritisation - FeedBacks
FrmFeedback2
Initial
Set Priorities
Previous
Next
Criterion 2
Preference >>
Preference <<
Neutral
Criterion 6
Accept and Solve
Save
Cancel
Snew/Sinit:
40.99
1-Snew/Sinit:
59.01
ASI Index:
0.9583
Parallel Diagr.
Star Diagr.
criterion 1
criterion 2
criterion 3
criterion 4
criterion 5
criterion 6

Criteria prioritisation - Utilisation

- Prioritisation of the criteria can be identified in many cases and lead to a more robust preference model
- Can resolve cases which presents straddling in criteria weights prioritization
- Increasing Robustness of the Preference Models can lead to :
  - Clarification of the DMs preference as far as the criteria Importance is concerned
  - The realization of their preference attitudes (by the DMs)
- Remaining Low Robustness can lead to:
  - Identification of the reasons why (in cases where is presented into particular criteria)
  - New feedbacks concerning the Problem Formulation, Alternative Actions evaluation on criteria, pre-ranking etc.

Conclusions - Perspectives

- Preference Models with low robustness include useful information about the structure of preferences.
- There is a need to identify why it is caused and how to exploit it.
- Visualisation and measurement of Robustness provides a better knowledge of the preference models and can support the exploration of the DM' preference structures.
- The new proposed Interactive feedbacks enrich the existing tools of D-A approach for detecting representative preference model with a better robustness.

The research is going on

- Focused on the standarisation of post dialogues for extracting preference information by the DMs indirectly.
- Test the proposed approach in many real world cases and in Group Decision Making.

Robust MCDA

ΜΙΑ ΠΟΛΥΚΡΙΤΗΡΙΑ ΜΕΘΟΔΟΛΟΓΙΑ ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΗ ΕΝΟΣ ΜΟΝΤΕΛΟΥ ΑΞΙΟΛΟΓΗΣΗΣ ΤΡΑΠΕΖΙΚΩΝ ΥΠΟΚΑΤΑΣΤΗΜΑΤΩΝ

ΘΑΛΗΣ – Πανεπιστήμιο Πειραιά
Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια
4th Workshop – Αθήνα 2-3 Απριλίου 2014

ΣΚΟΠΟΣ

- Δημιουργία ενός συστήματος κατάταξης του συνόλου των υποκαταστημάτων δικτύου ελληνικής εμπορικής τράπεζας
  - Τοποθέτηση υποκαταστημάτων σε ομοιογενείς κατηγορίες
  - Εύκολη προσαρμογή σε αλλαγές
  - Πρόβλεψη μεθοδολογίας προσθήκης ή κατάργησης κριτηρίων
  - Την ελάχιστη δυνατή διατάραξη της υπάρχουσας κατάστασης και την ομαλή μετάβαση από το υπάρχον σύστημα

ΔΕΔΟΜΕΝΑ

τα πιο αντιπροσωπευτικά ετήσια στοιχεία, για την τριετία 1999-2001, τα οποία αφορούν το σύνολο των υποκαταστημάτων του δικτύου (613 υποκαταστήματα)

ΕΡΓΑΣΙΕΣ

ΣΥΝΑΛΛΑΚΤΙΚΗ ΚΙΝΗΣΗ

ΠΙΝΑΚΑΣ ΚΡΙΤΗΡΙΩΝ

ΜΕΣΑ ΥΠΟΛΟΙΠΑ ΕΤΟΥΣ (σε εκατ, €)	*11) Ποσά Εντολών& Επιταγών*
1) Καταθέσεις (σε €)	*12) Ποσά Πιστωτικών Καρτών*
2) Καταθέσεις Συναλλάγματος	*13) Λοιπές Ωφέλειες (Προμήθειες Τραπεζικών Εργασιών)*
3) Προϊόντα D.R.	*14) Προμήθειες από Καταναλωτική Πίστη*
4) Χορηγήσεις	*15) Προμήθειες από Αμοιβαία Κεφάλαια*
5) Χορηγήσεις Συναλλάγματος	*16) Προμήθειες από Επενδυτικά Προϊόντα*
6) Δάνεια Καταναλωτικής& Στεγαστικής Πίστης	**ΣΥΝΑΛΛΑΚΤΙΚΗ ΚΙΝΗΣΗ** (σε χιλιάδες τεμάχια)
7) Ισχύουσες Εγγυητικές Επιστολές	*17) Εισαγωγές*
ΣΥΝΟΛΙΚΑ ΥΠΟΛΟΙΠΑ ΕΤΟΥΣ (σε εκατ, €)	*18) Εξαγωγές*
8) Εισαγωγές (Ποσά)	*19) Νέες Εκδοθείσες Πιστωτικές Κάρτες*
9) Εξαγωγές (Ποσά)	*20) Παραστατικά Ταμείου*
10) Αγορά& Πώληση Συναλλάγματος	*21) Κινήσεις ATM*

ΔΕΔΟΜΕΝΑ

- Για τα έτη 1999-2000, είναι γνωστές οι βαθμολογίες των υποκαταστημάτων και η ταξινόμησή τους σε δέκα διατεταγμένες κατηγορίες, σύμφωνα με το ισχύον σύστημα αξιολόγησης
- Για το έτος 2001, είναι γνωστή η ταξινόμηση των υποκαταστημάτων στις δέκα κατηγορίες, χωρίς όμως να είναι γνωστή η βαθμολογία τους

ΜΕΘΟΔΟΛΟΓΙΑ

- Ανάπτυξη ενός προσθετικού μοντέλου βαθμολόγησης των υποκαταστημάτων βάσει των δεδομένων για τα έτη 1999-2000
- Έλεγχος της αποτελεσματικότητας του μοντέλου με βάση τα δεδομένα του 2001
- Η ευστάθεια του μοντέλου ελέγχεται μέσω τεχνικών bootstrap

ΓΡΑΜΜΙΚΑ ΠΡΟΓΡΑΜΜΑΤΑ

- 1η νόρμα συντελεστών

$$\min \quad f=\sum_{i=1}^{1226}\left(d_i^+ + d_i^-\right)+k\sum_{j=1}^{21}a_j$$

υπό τους περιορισμούς

$$\sum_{j=1}^{21}a_j x_{ij}+d_i^+ - d_i^- = y_i,\ \forall i=1,\ldots,1226$$

$$a_j \ge 0,\ \ \forall j=1,\ldots,21$$

$$d_i^+, d_i^- \ge 0,\ \forall i=1,\ldots,1226$$

- Άπειρη νόρμα συντελεστών

$$\min \quad f=\sum_{i=1}^{1226}\left(d_i^+ + d_i^-\right)+kD$$

υπό τους περιορισμούς

$$\sum_{j=1}^{21}a_j x_{ij}+d_i^+ - d_i^- = y_i,\ \ \forall i=1,\ldots,1226$$

$$a_j \le D,\ \ \forall j=1,\ldots,21$$

$$a_j \ge 0,\ \ \forall j=1,\ldots,21$$

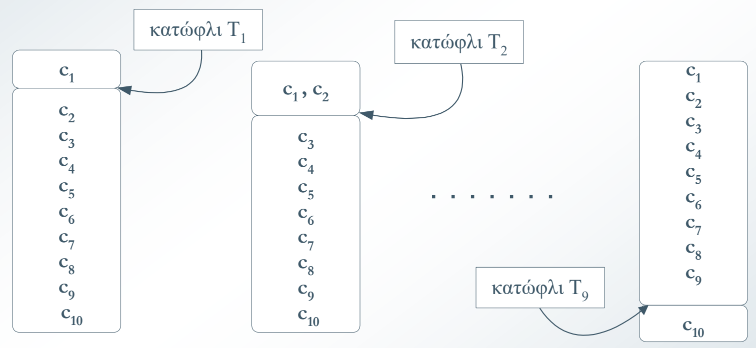
$$d_i^+, d_i^- \ge 0,\ \ \forall i=1,\ldots,1226$$

ΜΕΘΟΔΟΛΟΓΙΑ

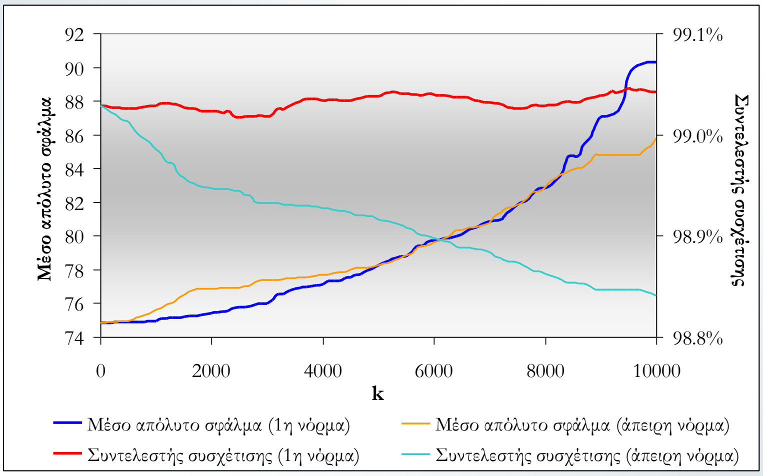
- Η ταξινόμηση γίνεται με την μέθοδο της ***εντροπίας***
- Σε ένα σύνολο **S**, **N** περιπτώσεων, αναζητούνται **k-1** κατώφλια $\mathbf{T_1>T_2>\ldots>T_{k-1}}$, που χωρίζουν το **S**, σε **k** διατεταγμένες κατηγορίες $\mathbf{c_1}$, $\mathbf{c_2}$, …, $\mathbf{c_k}$, έτσι ώστε η εντροπία του διαχωρισμού να ελαχιστοποιείται
- Η εντροπία, ενός συνόλου **S**, το οποίο χωρίζεται από κάποιο κατώφλι **T** σε δύο υποσύνολα $\mathbf{S_1}$, $\mathbf{S_2}$ τέτοια ώστε $\mathbf{S_2=S-S_1}$, είναι

$$E(T,S)=\frac{|S_1|}{N}Ent(S_1)+\frac{|S_2|}{N}Ent(S_2) \quad \text{όπου} \quad Ent(S)=-\sum_{i=1}^{k}P(c_i,S)\log_2 P(c_i,S)$$

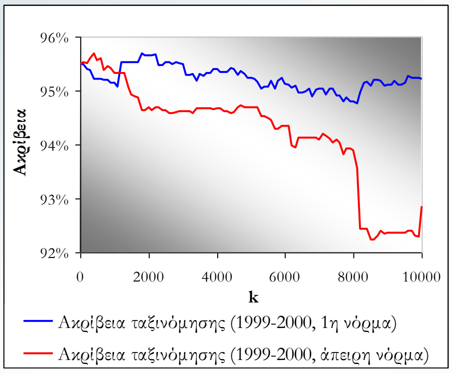
ΤΑΞΙΝΟΜΗΣΗ ΜΕ ΤΗΝ ΜΕΘΟΔΟ ΤΗΣ ΕΝΤΡΟΠΙΑΣ

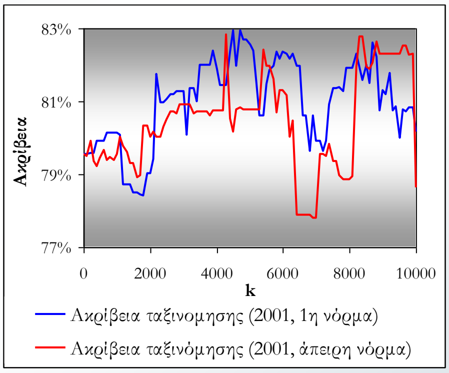


ΑΝΑΛΥΣΗ ΑΠΟΤΕΛΕΣΜΑΤΩΝ



ΑΠΟΤΕΛΕΣΜΑΤΑ ΤΑΞΙΝΟΜΗΣΗΣ





ΑΠΟΤΕΛΕΣΜΑΤΑ ΤΑΞΙΝΟΜΗΣΗΣ (2001, 1η νόρμα)

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	100,0%	-	-	-	-	-	-	-	-	-
C_2	-	100,0%	-	-	-	-	-	-	-	-
C_3	-	-	55,0%	45,0%	-	-	-	-	-	-
C_4	-	-	-	68,0%	32,0%	-	-	-	-	-
C_5	-	-	-	-	89,7%	10,3%	-	-	-	-
C_6	-	-	-	-	-	81,1%	17,8%	1,1%	-	-
C_7	-	-	-	-	-	1,4%	69,7%	27,6%	1,4%	-
C_8	-	-	-	-	-	-	-	80,5%	19,5%	-
C_9	-	-	-	-	-	-	-	-	85,5%	14,5%
C_{10}	-	-	-	-	-	-	-	-	-	100,0%
Συνολική ακρίβεια: 82,96%										

ΕΥΣΤΑΘΕΙΑ ΜΟΝΤΕΛΟΥ

	1η Νόρμα		*Άπειρη Νόρμα*	
	Bootstrap	*Πλήρες δείγμα*	***Bootstrap***	*Πλήρες δείγμα*
Μέγιστη τιμή	83,71%	82,96%	83,61%	82,84%
Μέση τιμή	80,25%	81,00%	80,05%	80,45%
Ελάχιστη τιμή	**76,08%**	78,40%	**76,50%**	77,81%

ΣΥΓΚΡΙΣΗ ΜΕ ΣΤΑΤΙΣΤΙΚΗ ΓΡΑΜΜΙΚΗ ΠΑΛΙΝΔΡΟΜΗΣΗ

	Γραμμικό Πρόγραμμα		*Στατιστική παλινδρόμηση*	
	1η Νόρμα	*Άπειρη Νόρμα*	*21 κριτήρια*	*9 κριτήρια*
Μέγιστη τιμή	82,96%	82,84%	**55,05%**	**73,08%**
Μέση τιμή	81,00%	80,45%		
Ελάχιστη τιμή	*78,40%*	*77,81%*		

ΕΠΙΔΡΑΣΗ ΚΡΙΤΗΡΙΩΝ

	1η νόρμα		Άπειρη νόρμα	
	Πλήρες δείγμα	Bootstrap	Πλήρες δείγμα	Bootstrap
α_1	32,8%	32,4%	24,8%	22,9%
α_4	13,1%	13,3%	12,8%	12,2%
α_{13}	12,6%	11,6%	11,3%	10,4%
α_{20}	-	-	10,5%	11,1%

ΣΥΜΠΕΡΑΣΜΑΤΑ & ΠΡΟΟΠΤΙΚΕΣ

- *Ανάπτυξη ενός συστήματος βαθμολόγησης και ταξινόμησης των υποκαταστημάτων μιας τράπεζας*
- ***Πλεονεκτήματα μοντέλου***
  - Περιορισμένες μεταβολές στην υπάρχουσα ταξινόμηση των υποκαταστημάτων
  - Υψηλή ευστάθεια σε μεταβολές του συνόλου αναφοράς
  - Εύκολα κατανοητό και άμεσο στη χρήση
  - Εύκολα προσαρμόσιμο σε νέα δεδομένα
- ***Μελλοντική έρευνα***
  - Περιορισμός εξεταζόμενων στοιχείων
  - Συνδυασμός με άλλες τεχνικές (DEA)
  - Προσδιορισμός παραγόντων που προσδιορίζουν τις μεταβολές στην αποτελεσματικότητα των υποκαταστημάτων
  - Κατασκευή ενός συνολικού δείκτη αποτελεσματικότητας της τράπεζας

Robust MCDA

The problem of robustness in the MUSA method: Theoretical developments and applications

Evangelos Grigoroudis, Yannis Politis
University of Piraeus – Research Team

ΘΑΛΗΣ – Πανεπιστήμιο Πειραιά
Μεθοδολογικές προσεγγίσεις για τη μελέτη της ευστάθειας σε προβλήματα λήψης αποφάσεων με πολλαπλά κριτήρια
4th Workshop – Αθήνα 2-3 Απριλίου 2014

Plan

- Introduction
- The MUSA method
  - Mathematical development
  - Stability analysis
  - Basic results
  - Fitting and robustness indicators
- Modeling additional information and properties
  - Desired properties
  - Preferences on criteria importance
  - Extension of the MUSA method
- Real-world application
- Conclusions

Introduction (1)

- The MUSA (Multicriteria Satisfaction Analysis) method is a preference disaggregation approach following the main principles of ordinal regression analysis.
- Additional constraints in the basic LP of the method may improve the stability of the basic MUSA model.
- These constraints may concern special properties for the assessed average indices and additional customer preferences about the importance of the criteria.

Introduction (2)

- Other extensions of the method include additional DMs' preferences or desired properties of the inferred preference system:
  - Hierarchy or interaction of criteria
  - Alternative objective functions (during the post-optimality analysis)
  - Different types of input data (ordinal/cardinal)
- Based on an extension of the MUSA method with the introduction of additional constraints, a real-world application in Greek mobile service providers is presented

The MUSA method

- Customer's global satisfaction is based on a set of criteria representing service characteristic dimensions.
- The main object of the MUSA method is the aggregation of individual judgments into a collective value function.
- The method is an ordinal regression-based approach used for the assessment of a set of collective value (satisfaction) functions in such a way that the global value (satisfaction) criterion becomes as consistent as possible with customers' judgments.

Mathematical development (1)

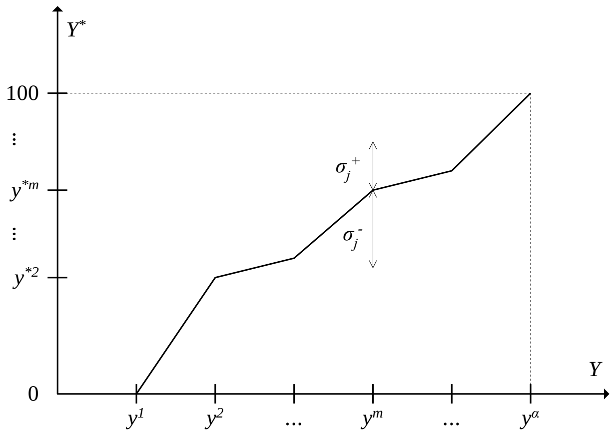
- MUSA is a preference disaggregation method used for the assessment of global and partial satisfaction functions Y^* and X_i^* respectively, given customers' judgments Y and X_i.

$$Y^* = \sum_{i=1}^{n} b_i X_i^* \quad \text{with} \quad \sum_{i=1}^{n} b_i = 1$$

- Introducing a double-error variable, the ordinal regression equation becomes:

$$\tilde{Y}^* = \sum_{i=1}^{n} b_i X_i^* - \sigma^+ + \sigma^-$$

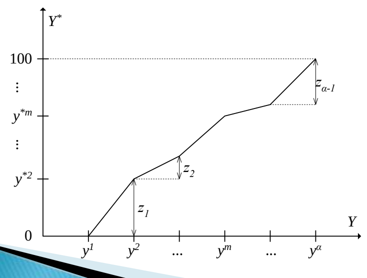
Mathematical development (2)

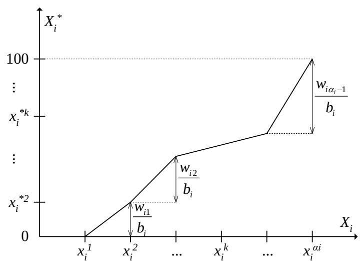


Mathematical development (3)

- The following transformations which represent the successive steps of the value functions Y^* and X_i^* can be introduced in the model

$$\begin{cases} z_m = y^{*m+1} - y^{*m} & \text{for } m = 1,2,\ldots,\alpha-1 \\ w_{ik} = b_i x_i^{*k+1} - b_i x_i^{*k} & \text{for } k = 1,2,\ldots,\alpha_i - 1 \text{ and } i = 1,2,\ldots,n \end{cases}$$





LP formulation

$$
\begin{cases}
[\min] F = \sum_{j=1}^{M} \sigma_j^+ + \sigma_j^- \\
\text{under the constraints} \\
\sum_{i=1}^{n} \sum_{k=1}^{x_i^j - 1} w_{ik} - \sum_{m=1}^{y^j - 1} z_m - \sigma_j^+ + \sigma_j^- = 0 \quad \text{for } j = 1,\ 2,\ \ldots,\ M \\
\sum_{m=1}^{\alpha - 1} z_m = 100 \\
\sum_{i=1}^{n} \sum_{k=1}^{\alpha_i - 1} w_{ik} = 100 \\
z_m \geq 0,\ w_{ik} \geq 0 \quad \forall\ m, i,\ and\ k \\
\sigma_j^+ \geq 0,\ \sigma_j^- \geq 0 \quad \text{for } j = 1,\ 2,\ \ldots,\ M
\end{cases}
$$

Strictly increasing value functions

- In several cases with unstable results, it appears that $y^{*m} = y^{*m+1}$ or $x_i^{*k} = x_i^{*k+1}$
- Cases where $b_i = 0$ for some criteria X_i should be avoided
- Assuming that Y^* and X_i^* are monotonic and strictly increasing functions and introducing preference thresholds may overcome these problems

$$
\begin{cases}
y^{*m+1} - y^{*m} \geq \gamma & \text{for } m = 1, 2, \ldots, \alpha - 1 \\
b_i x_i^{*k+1} - b_i x_i^{*k} \geq \gamma_i & \text{for } k = 1, 2, \ldots, \alpha_i - 1 \text{ and } i = 1, 2, \ldots, n
\end{cases}
$$

- where γ and γ_i are the preference thresholds for the value functions Y^* and X_i^*, respectively (with $\gamma,\ \gamma_i > 0$).

The generalized MUSA model

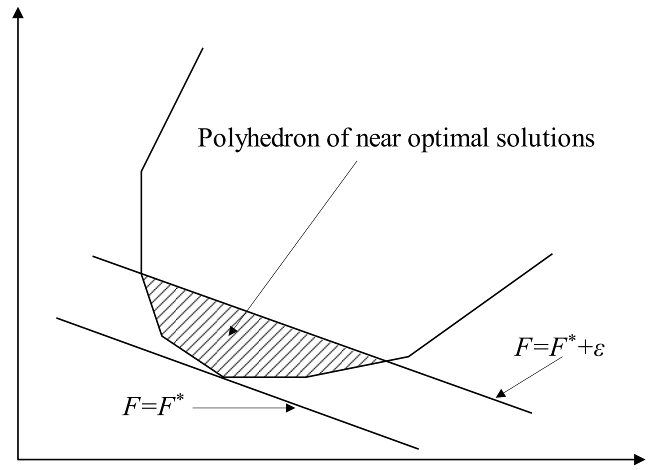
$$
\begin{cases}
[\min] F = \sum_{j=1}^{M} \sigma_j^{+} + \sigma_j^{-} \\
\text{subject to} \\
\sum_{i=1}^{n} \sum_{k=1}^{t_{ij}-1} w'_{ik} - \sum_{m=1}^{t_j-1} z'_m - \sigma_j^{+} + \sigma_j^{-} = \gamma(t_j - 1) - \sum_{i=1}^{n} \gamma_i (t_{ij} - 1) \quad \forall j \\
\sum_{m=1}^{\alpha-1} z'_m = 100 - \gamma(\alpha - 1) \\
\sum_{i=1}^{n} \sum_{k=1}^{\alpha_i - 1} w'_{ik} = 100 - \sum_{i=1}^{n} \gamma_i (\alpha_i - 1) \\
z'_m \geq 0,\ w'_{ik} \geq 0,\ \sigma_j^{+} \geq 0, \sigma_j^{-} \geq 0 \qquad \forall\, i, j, k, m
\end{cases}
$$

Post-optimality analysis (1)

- In several cases the problem of multiple or near optimal solutions appears.
- Stability analysis is considered as a post-optimality problem.
- This solution is calculated by *n* LPs (equal to the number of criteria), which maximize the weight of each criterion. These LPs have the following form:

$$
\begin{cases}
[\max] F' = \sum_{k=1}^{\alpha_i - 1} w_{ik} \qquad \text{for } i = 1,\ 2,\ \ldots,\ n \\
\text{under the constraints} \\
F \leq F^{*} + \varepsilon \\
\text{all the constraints of basic LP}
\end{cases}
$$

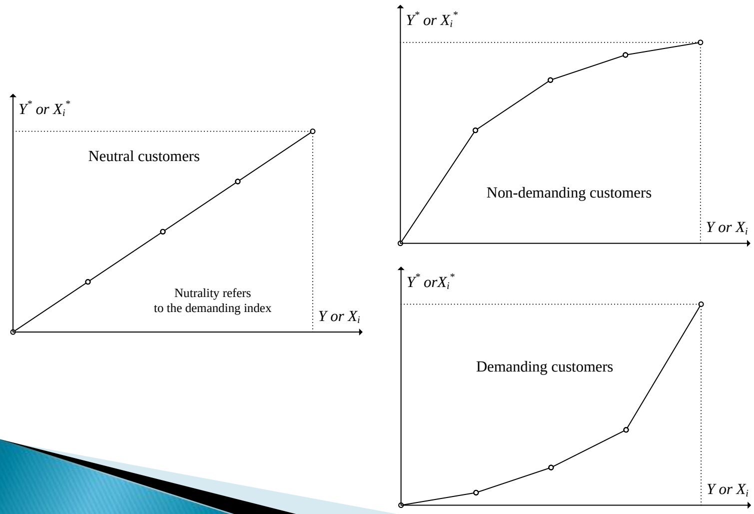
Post-optimality analysis (2)



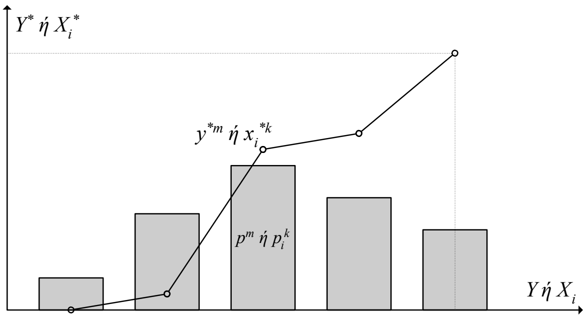
Results

- **Value functions:** they show the real value (in a normalized interval 0-100) that customers give for each level of the global or partial ordinal satisfaction scale.
- **Criteria weights:** they represent the relative importance of the assessed satisfaction dimensions.
- **Average satisfaction indices:** they show in a range 0-100% the level of customers' satisfaction and they can be considered as the basic performance norms; the average satisfaction indices are basically the mean value of the global and partial value functions.
- **Average demanding indices:** they are calculated according to the shape of global and partial value functions (normalized in the interval [-1, 1]), and they indicate customers' demanding level; they represent the average deviation of the estimated value functions from a "normal" (linear) function.

Value functions



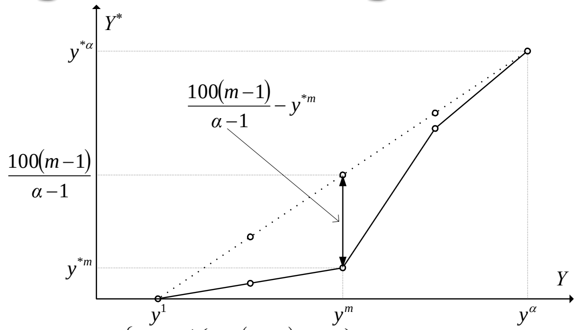
Average satisfaction indices



$$
\begin{cases}
S = \dfrac{1}{100}\displaystyle\sum_{m=1}^{\alpha} p^m y^{*m} \\
S_i = \dfrac{1}{100}\displaystyle\sum_{k=1}^{\alpha_i} p_i^k x_i^{*k} \quad \text{for } i = 1,\ 2,\ \ldots,\ n
\end{cases}
$$

where S and S_i are the average global and partial satisfaction indices, and p^m, p_i^k are the frequencies of customers belonging to the y^m and x_i^k satisfaction level, respectively.

Average demanding indices



$$
\begin{cases}
D = \dfrac{\displaystyle\sum_{m=1}^{\alpha-1}\left(\frac{100(m-1)}{\alpha-1} - y^{*m}\right)}{\displaystyle 100\sum_{m=1}^{\alpha-1}\frac{m-1}{\alpha-1}} & \text{for } \alpha > 2 \\[2ex]
D_i = \dfrac{\displaystyle\sum_{k=1}^{\alpha_i-1}\left(\frac{100(k-1)}{\alpha_i-1} - x_i^{*k}\right)}{\displaystyle 100\sum_{k=1}^{\alpha_i-1}\frac{k-1}{\alpha_i-1}} & \text{for } \alpha_i > 2 \text{ and } i = 1,2,\ldots,n
\end{cases}
$$

Average Fitting Indices (1)

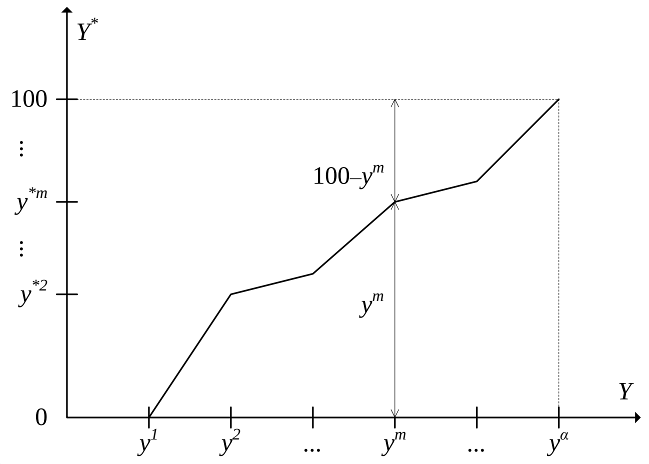
- The fitting level of the MUSA method refers to the assessment of a preference collective value system (value functions, weights, etc.) for the set of customers with the minimum possible errors.
- Alternative fitting indices:

$$AFI_1 = 1 - \frac{F^*}{100M}$$

$$AFI_2 = \frac{M_0}{M}$$

$$AFI_3 = 1 - \frac{F^*}{M\displaystyle\sum_{m=1}^{\alpha} p^m \max\left\{y^{*m}, 100 - y^{*m}\right\}}$$

Average Fitting Indices (2)



Average stability index

- The average stability index *ASI* is assessed as the mean value of the normalized standard deviation of the estimated weights during the post analysis step:

$$ASI = 1 - \frac{1}{n}\sum_{i=1}^{n}\frac{\sqrt{n\sum_{j=1}^{n}\left(b_i^j\right)^2 - \left(\sum_{j=1}^{n} b_i^j\right)^2}}{100\sqrt{n-1}}$$

Robust approaches

- A post-optimality analysis step is included in the original MUSA method.
- A generic robust approach:
  - Infer a collective preference model
  - Calculate a robustness measure (e.g., *ASI*)
  - Improve the robustness of the model (i.e., consider additional information):
    - Preferences on criteria importance (Grigoroudis and Siskos, 2010)
    - Interaction among criteria (Angilella et al., 2014)
    - Additional properties regarding the provided results (i.e., average satisfaction/demanding indices)

Modeling additional properties

- Average satisfaction indices:

$$S=\sum_{i=1}^{n} b_i S_i \Rightarrow \sum_{m=1}^{\alpha} p^m y^{*m}=\sum_{i=1}^{n} b_i \sum_{k=1}^{\alpha_i} p_i^k x_i^{*k} \Rightarrow \sum_{m=2}^{\alpha} p^m \sum_{t=1}^{m-1} z_t=\sum_{i=1}^{n}\sum_{k=2}^{\alpha_i} p_i^k \sum_{t=1}^{k-1} w_{it}$$

- Average demanding indices:

$$D=\sum_{i=1}^{n} b_i D_i \Rightarrow \frac{\sum_{m=1}^{\alpha-1} 100(m-1)-(\alpha-1)\sum_{t=1}^{m-1} z_t}{\alpha(\alpha-1)}=\sum_{i=1}^{n}\frac{\sum_{k=1}^{\alpha_i-1}(k-1)\sum_{t=1}^{\alpha_i-1} w_{it}-(\alpha_i-1)\sum_{t=1}^{k-1} w_{it}}{\alpha_i(\alpha_i-1)}$$

Desired Properties of the Results (1)

- A linkage between global and partial average satisfaction indices may be assumed, In particular, the global average satisfaction index S is assessed as a weighted sum of the partial satisfaction indices S_i:

$$S = \sum_{i=1}^{n} b_i S_i \Leftrightarrow \sum_{m=1}^{\alpha} p^m y^{*m} = \sum_{i=1}^{n} b_i \sum_{k=1}^{\alpha_i} p_i^k x_i^{*k}$$

or

$$\sum_{m=2}^{\alpha} p^m \sum_{t=1}^{m-1} z_t = \sum_{i=1}^{n} \sum_{k=2}^{\alpha_i} p_i^k \sum_{t=1}^{k-1} w_{it}$$

- In the case of the generalized MUSA method, the preference thresholds γ and γ_i should be introduced, and the previous equation is written:

$$\sum_{i=1}^{n} \sum_{k=2}^{\alpha_i} p_i^k \sum_{t=1}^{k-1} w_{it} - \sum_{m=2}^{\alpha} p^m \sum_{t=1}^{m-1} z_t = \sum_{m=2}^{\alpha} p^m \gamma (m-1) - \sum_{i=1}^{n} \sum_{k=2}^{\alpha_i} p_i^k \gamma_i (k-1)$$

Desired Properties of the Results (2)

- Similarly, a weighted sum formula may be assumed for the average demanding indices:

$$D = \sum_{i=1}^{n} b_i D_i$$

- The previous equation can be written in terms of the MUSA variables:

$$\frac{\sum_{m=1}^{\alpha-1} 100(m-1) - (\alpha-1) \sum_{t=1}^{m-1} z_t}{\alpha(\alpha-1)} = \sum_{i=1}^{n} \frac{\sum_{k=1}^{\alpha_i -1} (k-1) \sum_{t=1}^{\alpha_i -1} w_{it} - (\alpha_i - 1) \sum_{t=1}^{k-1} w_{it}}{\alpha_i (\alpha_i - 1)}$$

- The above equations about satisfaction and demanding indices may be introduced as additional constraints in the basic MUSA LP

Desired Properties of the Results (3)

- Add additional constraints to the basic LP formulation.
- In the general case, these constraints may lead to infeasible solutions, thus:
  - They should be modeled using a double error variable:

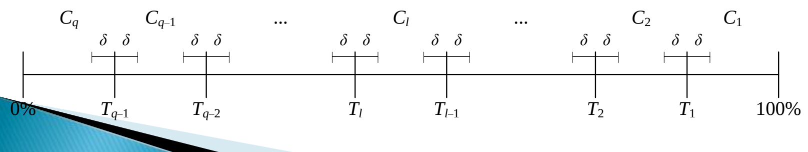
$$\sum_{i=1}^{n}\sum_{k=2}^{\alpha_i} p_i^k \sum_{t=1}^{k-1} w_{it} - \sum_{m=2}^{\alpha} p^m \sum_{t=1}^{m-1} z_t - es^+ + es^- = 0$$

$$\sum_{i=1}^{n} \frac{\sum_{k=1}^{\alpha_i-1}(k-1)\sum_{t=1}^{\alpha_i-1} w_{it} - (\alpha_i-1)\sum_{t=1}^{k-1} w_{it}}{\alpha_i(\alpha_i-1)} - \frac{\sum_{m=1}^{\alpha-1}100(m-1)-(\alpha-1)\sum_{t=1}^{m-1} z_t}{\alpha(\alpha-1)} - ed^+ + ed^- = 0$$

  - In this case, a MOLP approach may be applied (e.g., compromise programming)

Introducing information about the importance of the criteria

- A customer satisfaction survey may include, besides the usual performance questions, preferences about the importance of the criteria.
- Using such questions, customers are asked either to judge the importance of a satisfaction criterion using a predefined ordinal scale, or rank the set of satisfaction criteria according to their importance.
- Based on such importance questions, each one of the satisfaction criteria can be placed in one of the following categories $C_1, C_2, \ldots, C_q$, where C_1 is the most important criterion class and C_q is the less important criterion class. Considering that C_l, with l the class index, are ordered in a 0-100% scale, there are T_{q-1} thresholds, which define the rank and, therefore, label each one of the classes.
- Thus, the evaluation of preference importance classes C_l is similar to the estimation of thresholds T_l.



The WORT (Weights evaluation using Ordinal Regression Techniques) model

$$[\min] \quad F_2 = \sum_j \sum_i S_{ij}^+ + S_{ij}^-$$

$$\left.\begin{array}{l}
\sum_{t=1}^{a_i-1} w_{it} - 100\ T_1 - \delta + S_{ij}^- > 0, \quad \hat{b}_{ij} \in C_1 \\
\left.\begin{array}{l}
\sum_{t=1}^{a_i-1} w_{it} - 100\ T_{l-1} + \delta - S_{ij}^+ < 0 \\
\sum_{t=1}^{a_i-1} w_{it} - 100\ T_l - \delta + S_{ij}^- \geq 0
\end{array}\right\}, \hat{b}_{ij} \in C_l,\ l = 2,\dots,q-1 \\
\sum_{t=1}^{a_i-1} w_{it} - 100\ T_{q-1} + \delta - S_{ij}^+ < 0, \quad \hat{b}_{ij} \in C_q
\end{array}\right\} \quad \forall \quad i = 1,2,\dots,n \quad \text{και} \quad j = 1,2,\dots,M$$

$$\sum_{i=1}^{n} \sum_{k=1}^{a_i-1} w_{ik} = 100$$

$$T_{q-1} \quad \geq \quad \lambda$$

$$T_{q-2} - T_{q-1} \quad \geq \quad \lambda$$

$$\vdots$$

$$T_1 - T_2 \quad \geq \quad \lambda$$

$$w_{ik}, S_{ij}^+, S_{ij}^- \geq 0, \forall\ i, j, k$$

Were, δ is a small positive number, which is used in order to avoid cases where $b_{ij} = T_l\ \forall l$ and λ a minimum value introduced to increase the discrimination of the importance classes

Extension of the MUSA method

$$\begin{cases}
[\min] F = \sum_{j=1}^{M} \sigma_j^+ + \sigma_j^- \\
[\min] \Phi = \sum_{i=1}^{n} \sum_{j=1}^{M} S_{ij}^+ + S_{ij}^- \\
[\min] \varphi = es^+ + es^- + ed^+ + ed^-
\end{cases}$$

subject to

all the constraints of the basic MUSA method

constraints regarding the desired properties of S and D

constraints regarding the criteria importance preferences

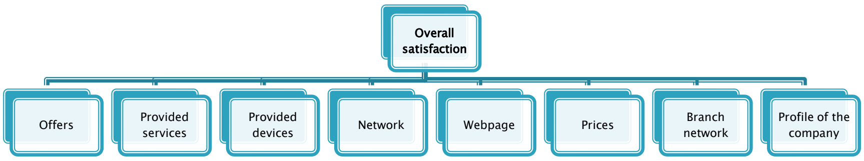
Optimization Procedure (lexicographic approach)

- Step 1:
  Min F subject to all constraints of the examined problem
- Step 2 (and 3):
  Min Φ (or φ) subject to all constraints of the examined problem and $F \leq F^{*}+\varepsilon_1$
- Final step:
  Max b_i subject to all constraints of the examined problem and
  $F \leq F^{*}+\varepsilon_1$, $\Phi \leq \Phi^{*} + \varepsilon_2$, $\varphi \leq \varphi^{*} + \varepsilon_3$

Real-world application

- Case study: Analysis of service quality of mobile service providers in Greece
- Sample size: 80 questionnaires
- Sample proportion:
  - Cosmote (57.5%)
  - Vodafone (22.5%)
  - Wind (20.0%)
- Data:
  - Performance questions
  - Ranking of the criteria from the most to the least important one

Satisfaction criteria



Results – Comparison (1)

	AFI_1	AFI_2	AFI_3	ASI
Original MUSA method	95.08%	17.50%	93.39%	79.11%
Extension of the MUSA method	94.58% (−0.53%)	7.50% (−57.14%)	91.92% (−2.25%)	86.94% (+9.90%)

Results – Comparison (2)

	Criteria weights							
Criteria	*Offers*	*Provided services*	*Provided devices*	*Network*	*Webpage*	*Charges*	*Branch network*	*Profile of the company*
Original MUSA method	9.23%	10.46%	12.50%	9.67%	10.46%	10.46%	10.46%	26.75%
Extension of the MUSA method	8.74%	9.45%	11.15%	11.31%	9.48%	9.51%	9.48%	30.88%

Conclusions

- The MUSA method is a rather flexible approach and thus several extensions may be developed taking into account additional information or data.
- Approaches to improve robustness → Consider additional information:
  - Preferences from customers (e.g., importance of criteria)
  - Model properties
- Future research:
  - Perform a simulation study
  - Study the impact of model parameters
  - Develop additional measures of robustness
  - Consider a non-collective approach