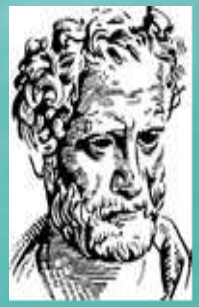


ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ

Τμήμα Μηχανικών Παραγωγής & Διοίκησης

Π.Μ.Σ. «Διοίκηση Κοινοτομίας, Τεχνολογίας & Επιχειρήσεων»

ΔΛΠΕ-5 Ασφάλεια Συστημάτων & Διαχείριση Κινδύνων

Δρ Παναγιώτης Κ. Μαρχαβίλας

Διπλ. Ηλεκ/γος Μηχ/κός & Μηχ/κός Η/Υ (Dipl., MSc., PhD[2])

3η Διάλεξη, Ξάνθη 2019

Τεχνικές και Μέθοδοι Υπολογισμού, Αξιολόγησης και Εκτίμησης της Διακινδύνευσης – Επικινδυνότητας

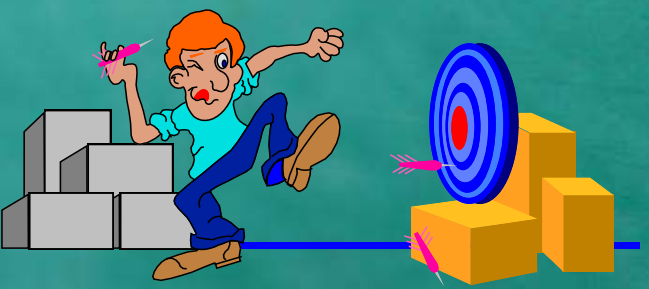
Στόχος:

(i) Ο εντοπισμός, η επισκόπηση, και η συστηματική ταξινόμηση **υπαρχόντων**, και

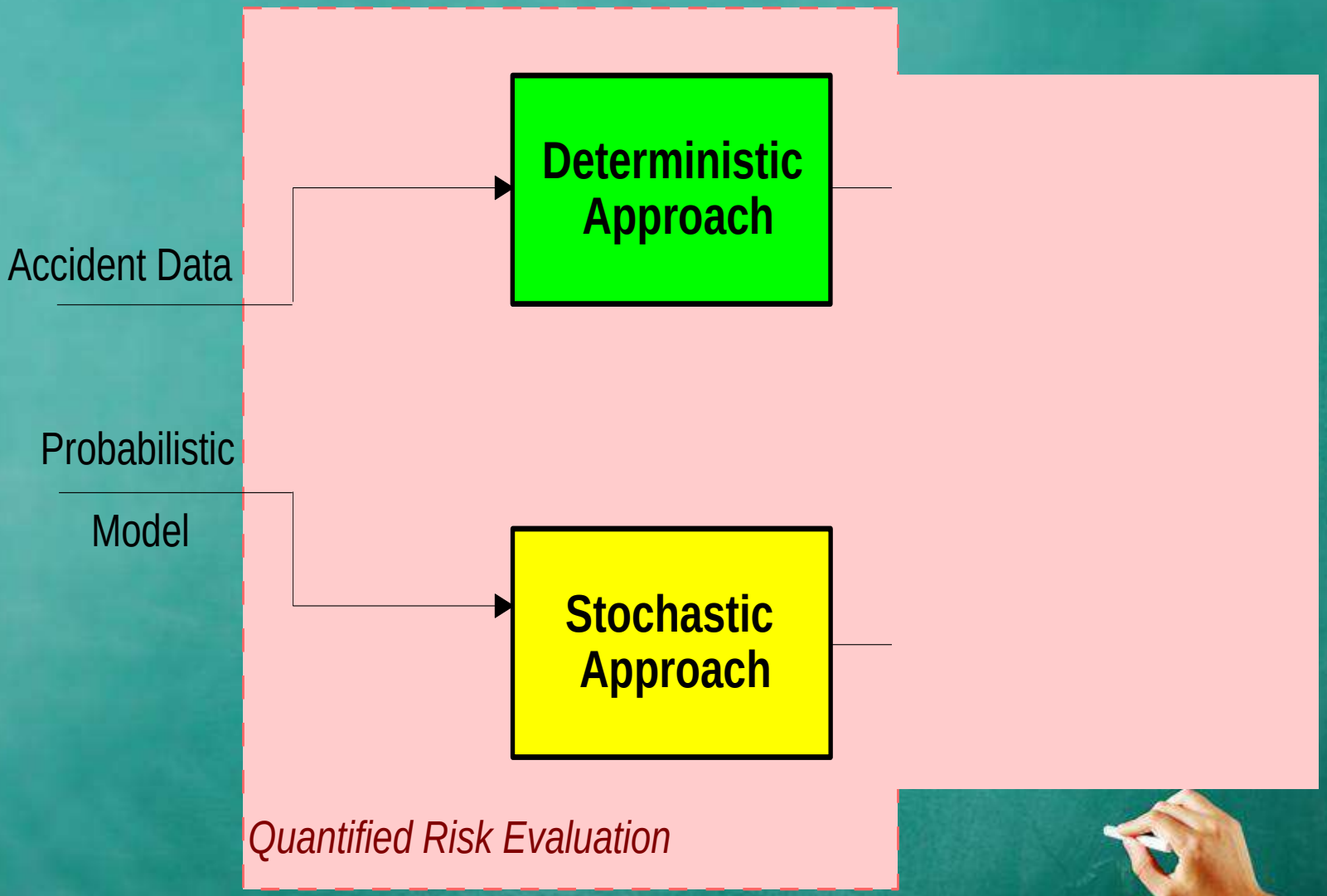
(ii) η ανάπτυξη **νέων**,

τεχνικών ανάλυσης, υπολογισμού, αξιολόγησης και εκτίμησης της **επικινδυνότητας ή διακινδύνευσης** (risk), στον τομέα της ασφάλειας εργασίας,

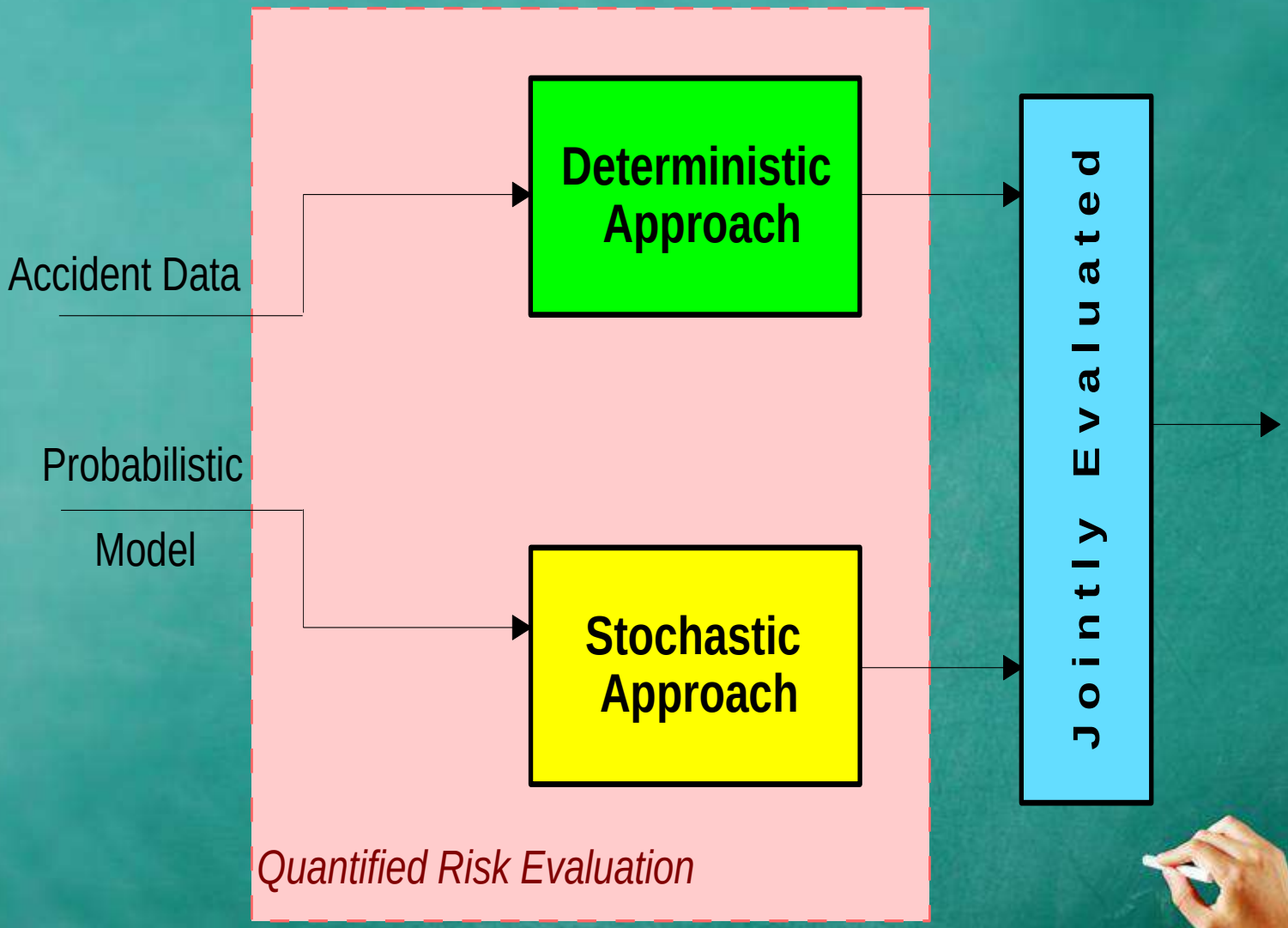
με έμφαση:
στη **Βιομηχανία** και τις **Κατασκευές Τεχνικών Έργων**.



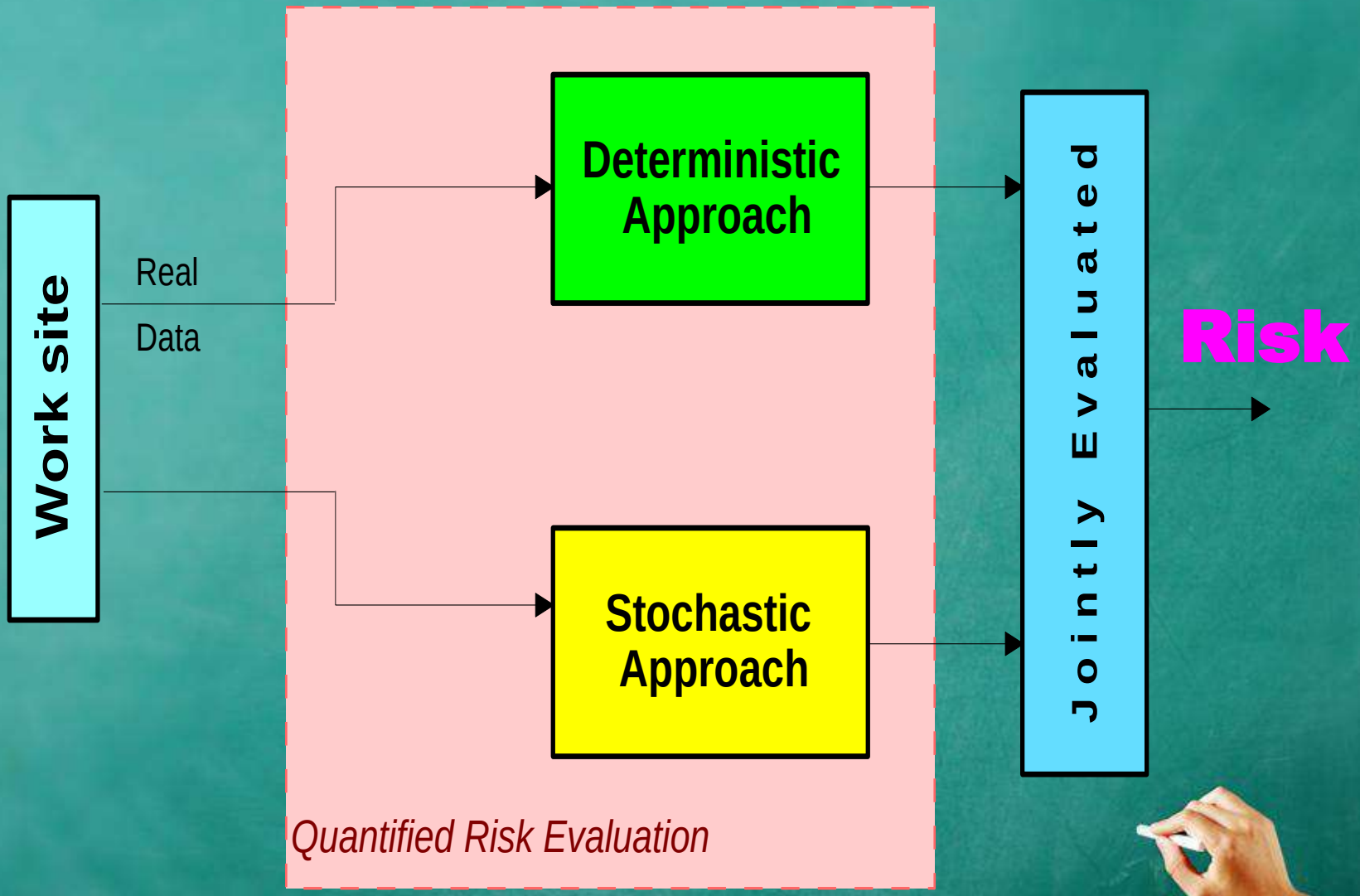
Βασική ιδέα : Η "σύντηξη" ή σύνθεση ΣΤΟΧΑΣΤΙΚΩΝ (Πιθανοκρατικών) & ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΩΝ (Αιτιοκρατικών) τεχνικών



Βασική ιδέα : Η "σύντηξη" ή σύνθεση ΣΤΟΧΑΣΤΙΚΩΝ (Πιθανοκρατικών) & ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΩΝ (Αιτιοκρατικών) τεχνικών



Βασική ιδέα : Η "σύντηξη" ή σύνθεση ΣΤΟΧΑΣΤΙΚΩΝ (Πιθανοκρατικών) & ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΩΝ (Αιτιοκρατικών) τεχνικών



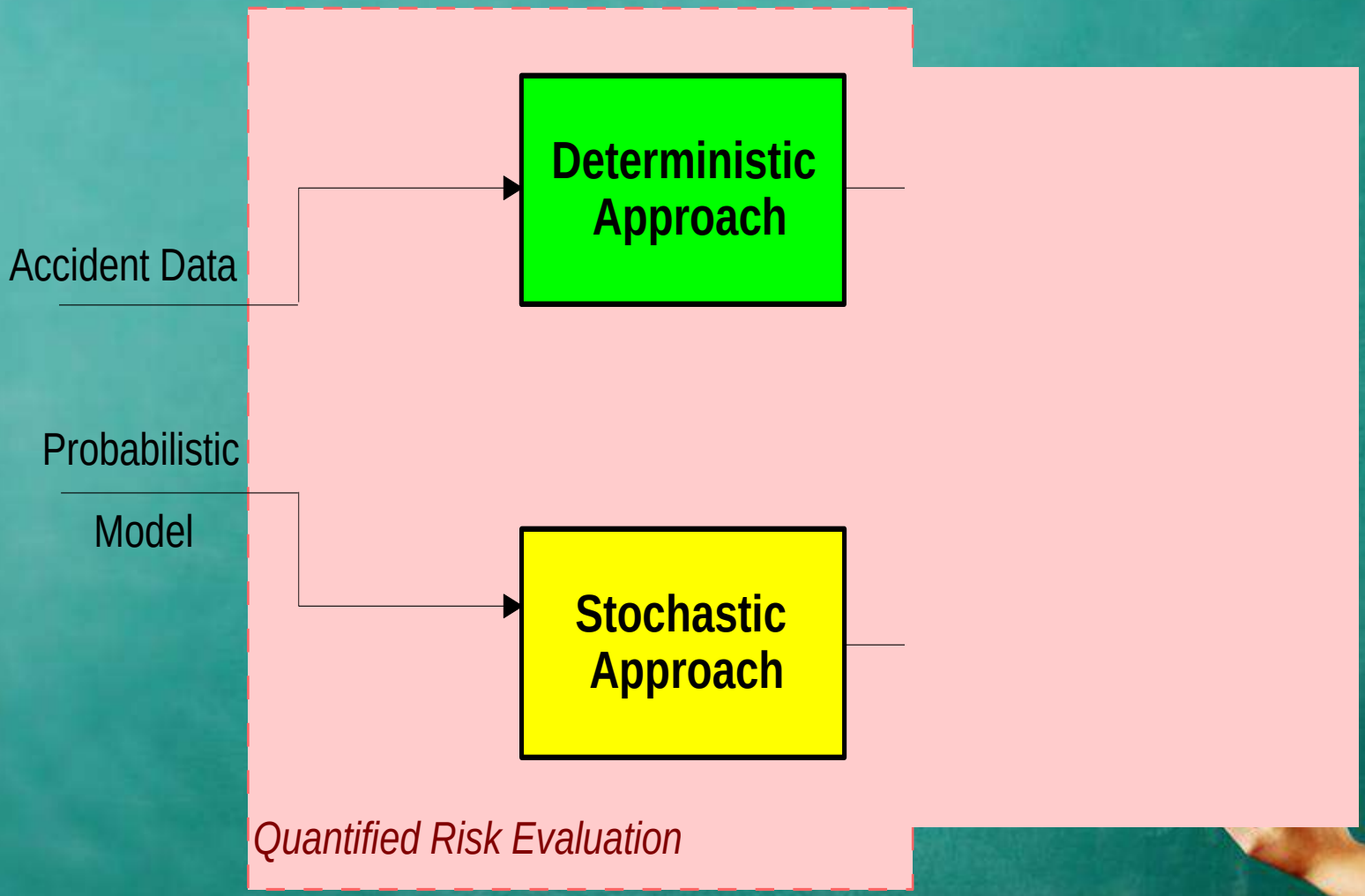
Τεχνικές ανάλυσης και εκτίμησης της επικινδυνότητας
(1η κατηγοριοποίηση)

α) **ΣΤΟΧΑΣΤΙΚΕΣ (Πιθανοκρατικές)**

β) **ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΕΣ (Αιτιοκρατικές)**

Τεχνικές ανάλυσης και εκτίμησης της επικινδυνότητας

(1η κατηγοριοποίηση)



α) **Στοχαστικές (Πιθανοκρατικές)**

Stochastic (random) methods by using **probabilistic** models, contribute in "***a priori***" risk analysis and assessment

* *A priori knowledge is independent of experience*

* *The quantity of Risk (R) is calculated with a probability of*

P(R)

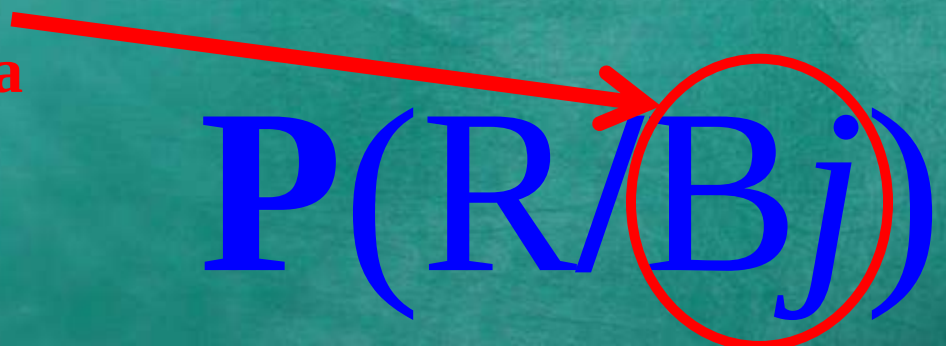
β) **Ντετερμινιστικές (Αιτιοκρατικές)**

Deterministic methods contribute in "***a posteriori***" risk analysis and assessment

* ***A posteriori*** *knowledge is* ***dependent*** *on experience or empirical evidence*

- *The quantity of Risk (R) is calculated with the conditional probability of*

B1, B2, …
accident data



Τεχνικές ανάλυσης και εκτίμησης της επικινδυνότητας

(2η κατηγοριοποίηση)

α) **ποιοτικές**

β) **ποσοτικές**

γ) **υβριδικές**

Ποιοτικές τεχνικές

Βασίζονται: σε **αναλυτικές** διαδικασίες **υπολογισμού** συγκεκριμένων και κατάλληλα ορισμένων μεγεθών

Προϋποθέτουν: την **εμπειρία** και την κριτική **ικανότητα** του αναλυτή

Ενσωματώνουν: υφιστάμενες **νομοθετικές** διατάξεις, διαδικασίες και πρακτικές

Πετυχαίνουν: ποιοτική διαβάθμιση του ρίσκου

Ποσοτικές τεχνικές

Η **επικινδυνότητα**

- θεωρείται ως: **μετρήσιμο** μέγεθος
- εκφράζεται με: **μαθηματική** σχέση

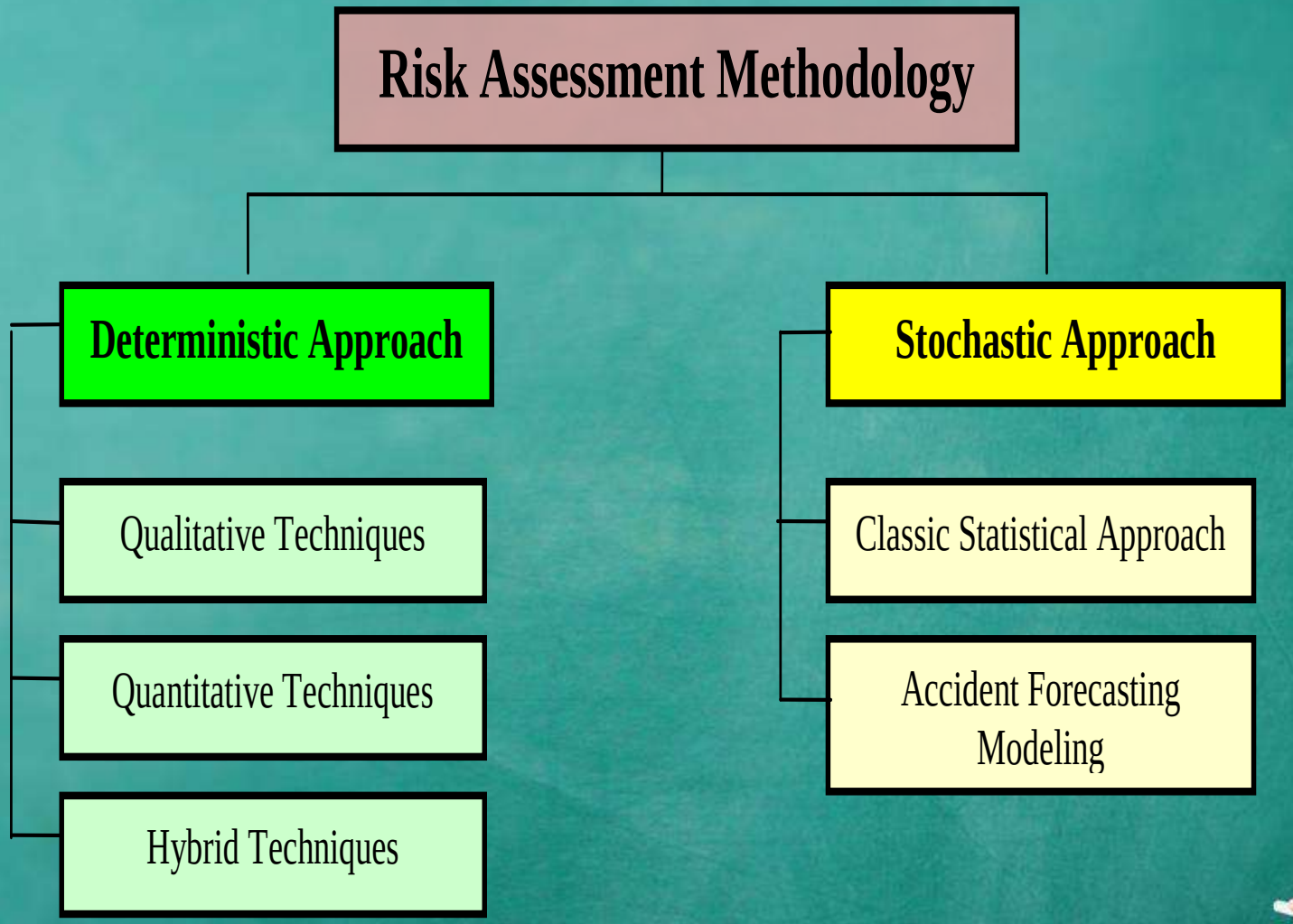
Υβριδικές τεχνικές

* Συνδυασμός **ποιοτικών** και **ποσοτικών** τεχνικών

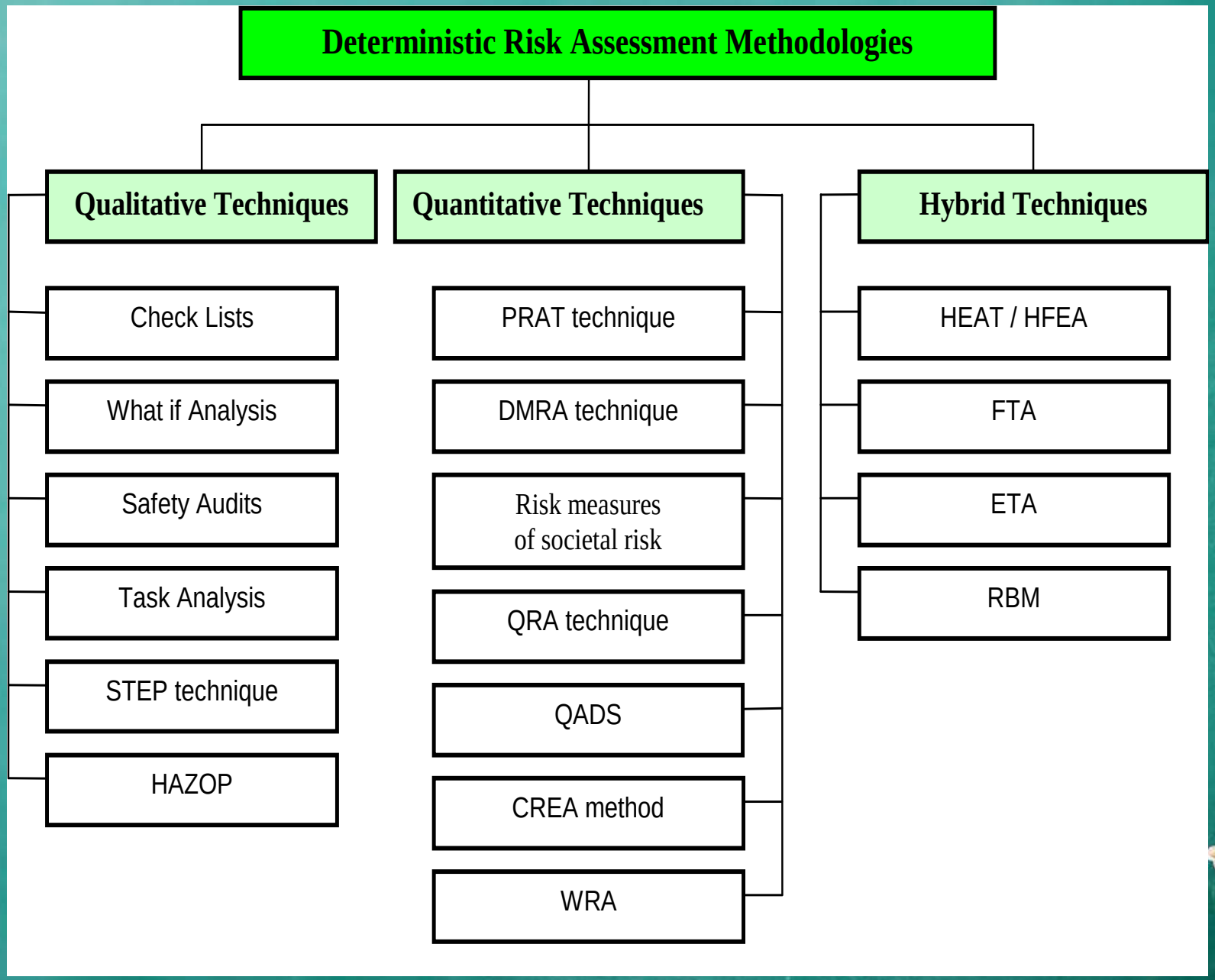
* Παρουσιάζουν αυξημένη **πολυπλοκότητα** λόγω της **ad hoc** φύσης τους

* **Δεν έχουν** εξαπλωθεί επαρκώς

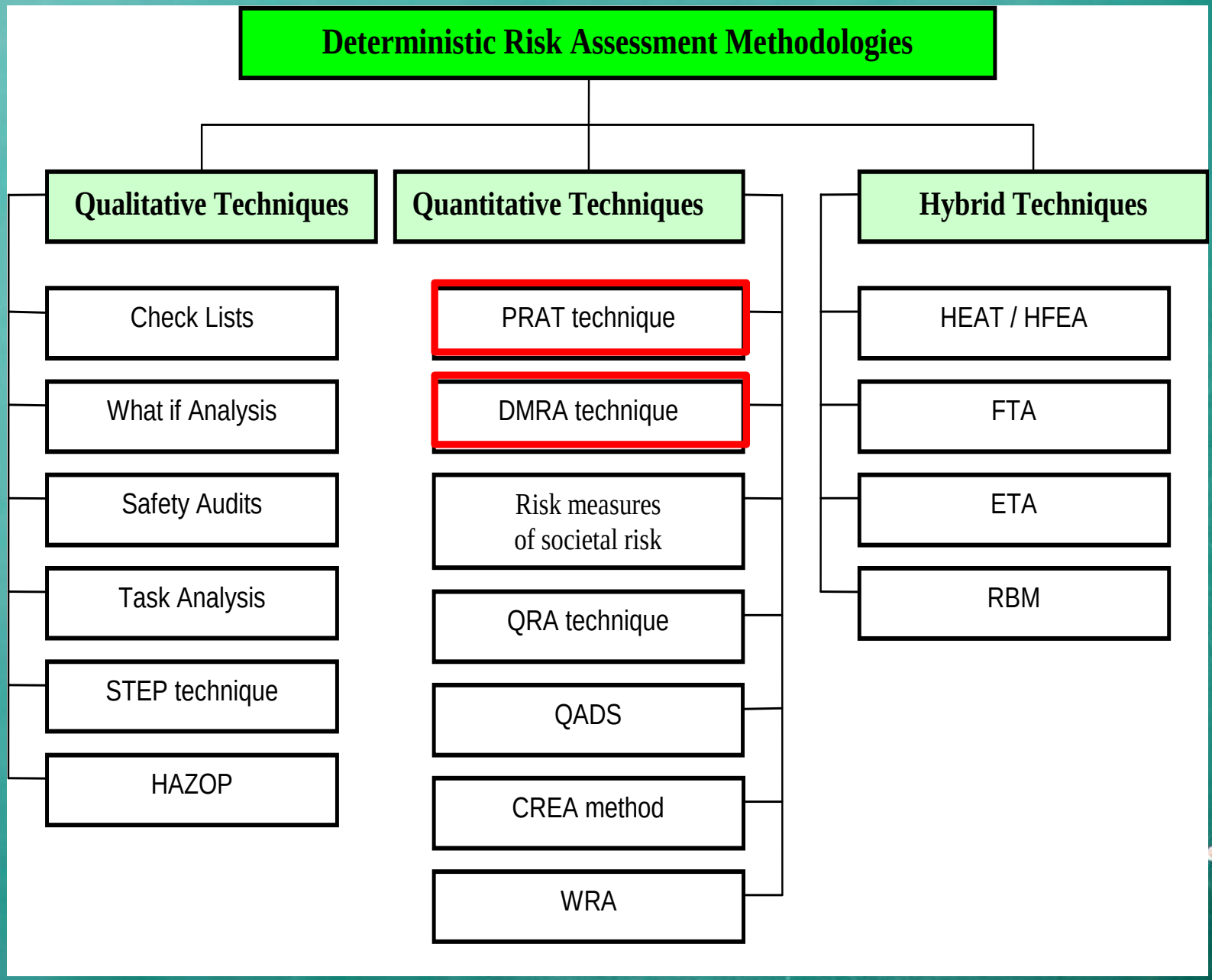
Τεχνικές ανάλυσης & εκτίμησης της επικινδυνότητας



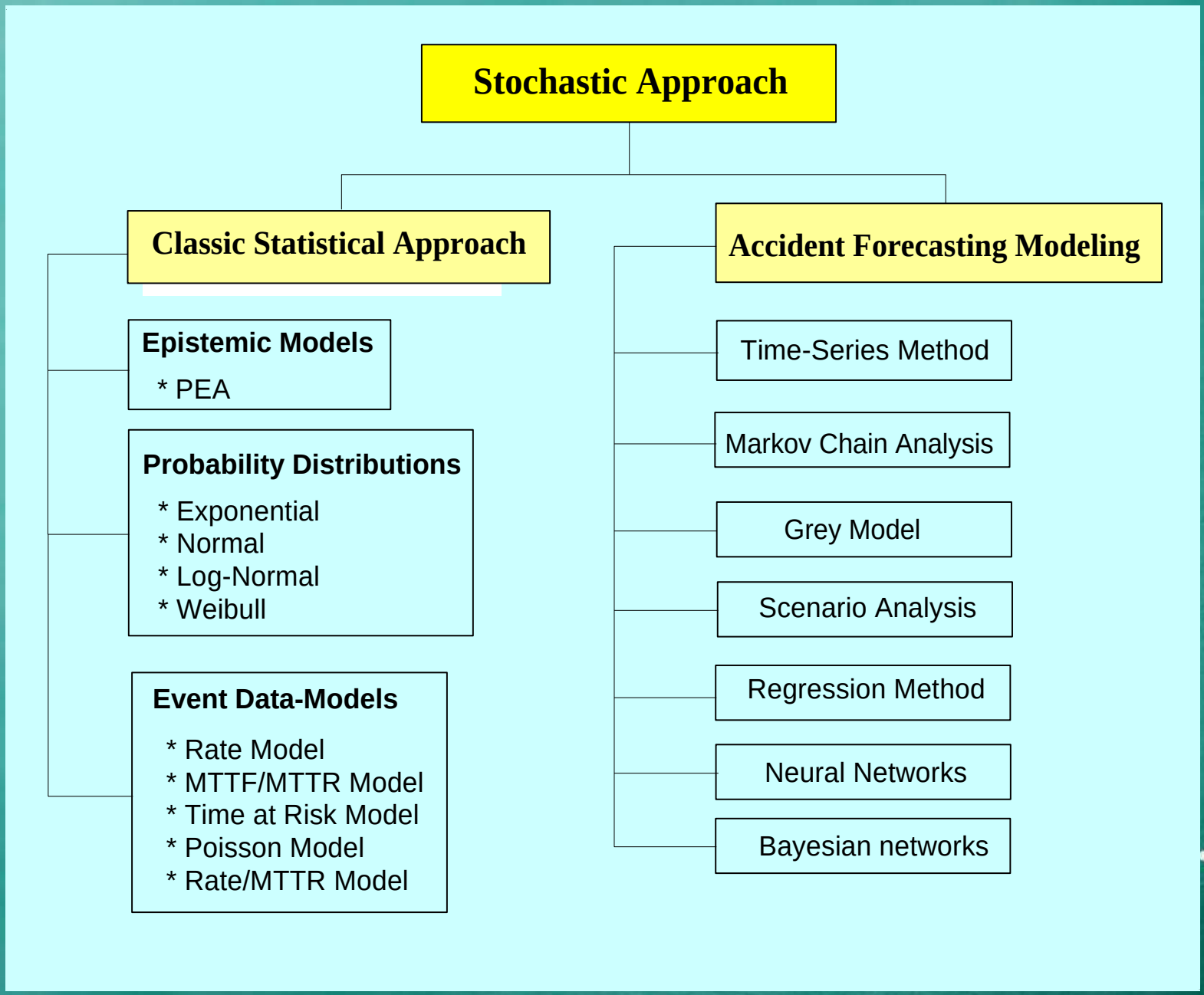
Αιτιοκρατικές Τεχνικές



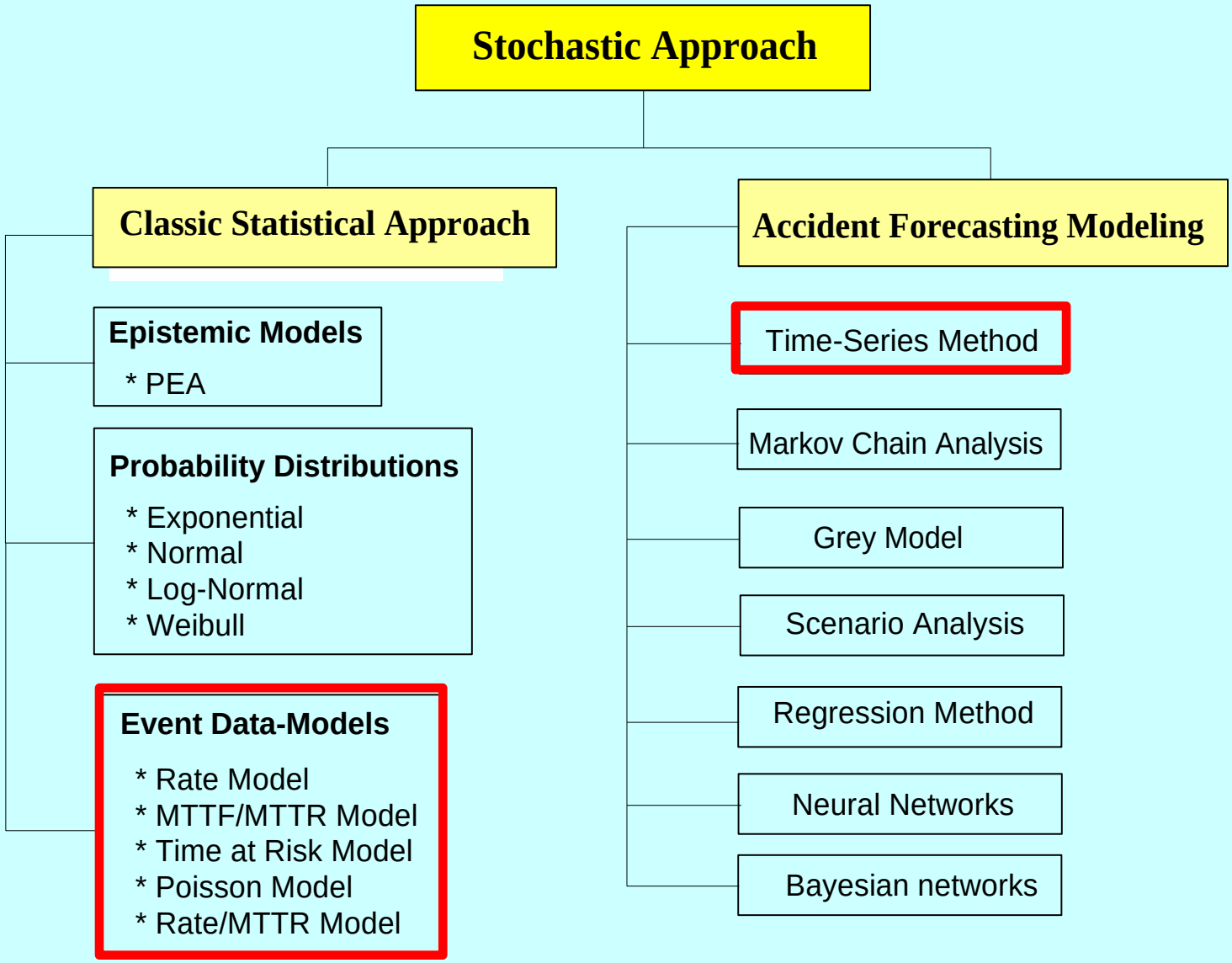
Αιτιοκρατικές Τεχνικές



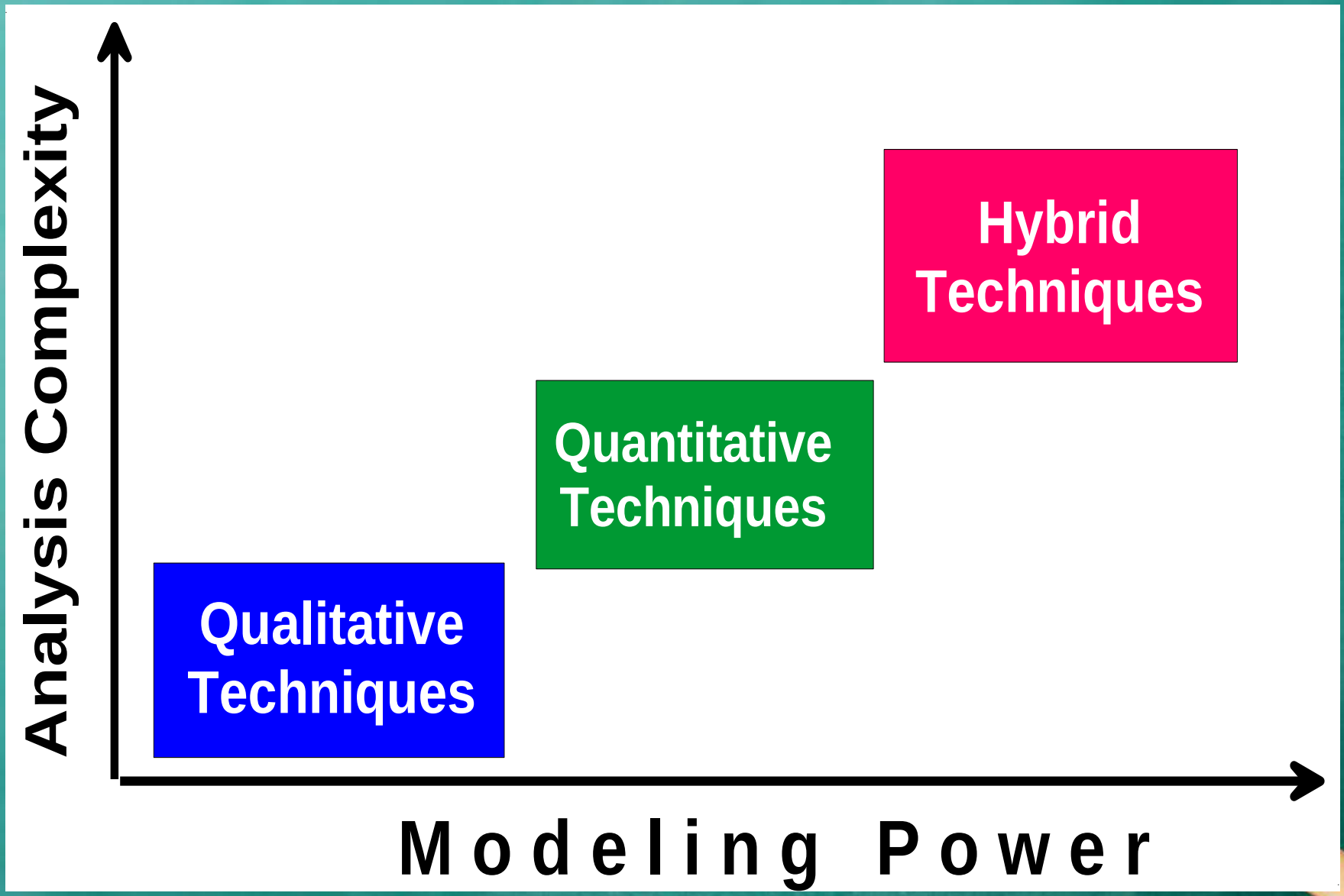
Πιθανοκρατικές Τεχνικές



Πιθανοκρατικές Τεχνικές



The relation of modeling-power and analysis-complexity for QN/QL/HB classes



Ανάπτυξη δύο νέων ποσοτικών τεχνικών:

* **PRAT** (Proportional Risk Assessment Technique)

* **DMRA** (Decision Matrix Risk Assessment)

Εφαρμόσθηκαν ως μελέτη περίπτωσης (**case study**), σε:

* **Βιομηχανία Διέλασης Αλουμινίου**

* **Κατασκευές τεχνικών έργων**

*(**J.LPPI**: Marhavilas and Koulouriotis, 2008a;*
***J.ESTR**: Marhavilas, 2009a)*

Πηγές δεδομένων: Ι.Κ.Α., Σ.Ε.Π.Ε., ΔΕΗ

- της Βιομηχανίας

- των Κατασκευών

Αναλογική Ποσοτική Τεχνική (PRAT)

Η επικινδυνότητα παρουσιάζεται σαν ένα φυσικό, μετρήσιμο μέγεθος (R)

$$R = f(x, y, z, \ldots)$$

Αναλογική Ποσοτική Τεχνική (PRAT)

Η επικινδυνότητα παρουσιάζεται σαν ένα φυσικό, μετρήσιμο μέγεθος (R)

$$R = f\,(P, S, F, \ldots)$$

R: the Risk

P: the Probability Factor

S: the Severity of Harm Factor

F: the Frequency (or the Exposure) Factor

Αναλογική Ποσοτική Τεχνική (PRA)

Η επικινδυνότητα παρουσιάζεται σαν ένα φυσικό, μετρήσιμο μέγεθος (R)

$$R = P * S * F$$

R: the Risk

P: the Probability Factor

S: the Severity of Harm Factor

F: the Frequency (or the Exposure) Factor

Fine & Kinney (1971) and Hammer (1972)

Δείκτης Πιθανότητας P	Περιγραφή ανεπιθύμητου γεγονότος
10	Αναπόφευκτο
9	Σχεδόν σίγουρο
8	Πολύ πιθανό
7	Πιθανό
6	Πιθανότητα ελαφρώς μεγαλύτερη του 50%
5	Πιθανότητα 50%
4	Πιθανότητα ελαφρώς μικρότερη του 50%
3	Σχεδόν απίθανο
2	Πολύ απίθανο
1	Απίθανο

Δείκτης Σοβαρότητας Αποτελέσματος (S)	Περιγραφή ανεπιθύμητου γεγονότος
10	Θάνατος
9	Μόνιμη ολική ανικανότητα
8	Μόνιμη σοβαρή ανικανότητα
7	Μόνιμη ελαφρά ανικανότητα
6	Απουσία από την εργασία για περισσότερες από τρεις εβδομάδες και επιστροφή με προβλήματα υγείας
5	Απουσία από την εργασία για περισσότερες από τρεις εβδομάδες και επιστροφή με πλήρη ανάρρωση
4	Απουσία από την εργασία για περισσότερες από τρεις ημέρες και λιγότερο από τρεις εβδομάδες και επιστροφή με πλήρη ανάρρωση
3	Απουσία από την εργασία για λιγότερο από τρεις ημέρες και επιστροφή με πλήρη ανάρρωση
2	Ελαφρός τραυματισμός χωρίς απώλεια ημερών εργασίας και πλήρη ανάρρωση
1	Καμία ανθρώπινη βλάβη

Δείκτης συχνότητας (F)	Περιγραφή ανεπιθύμητου γεγονότος
10	Μόνιμη παρουσία βλάβης
9	Η βλάβη εμφανίζεται ανά 30 δευτερόλεπτα
8	Η βλάβη εμφανίζεται ανά λεπτό
7	Η βλάβη εμφανίζεται κάθε 30 λεπτά
6	Η βλάβη εμφανίζεται κάθε μία ώρα
5	Η βλάβη εμφανίζεται σε κάθε βάρδια
4	Η βλάβη εμφανίζεται μία φορά την εβδομάδα
3	Η βλάβη εμφανίζεται μία φορά το μήνα
2	Η βλάβη εμφανίζεται μία φορά το χρόνο
1	Η βλάβη εμφανίζεται μία φορά στα πέντε χρόνια

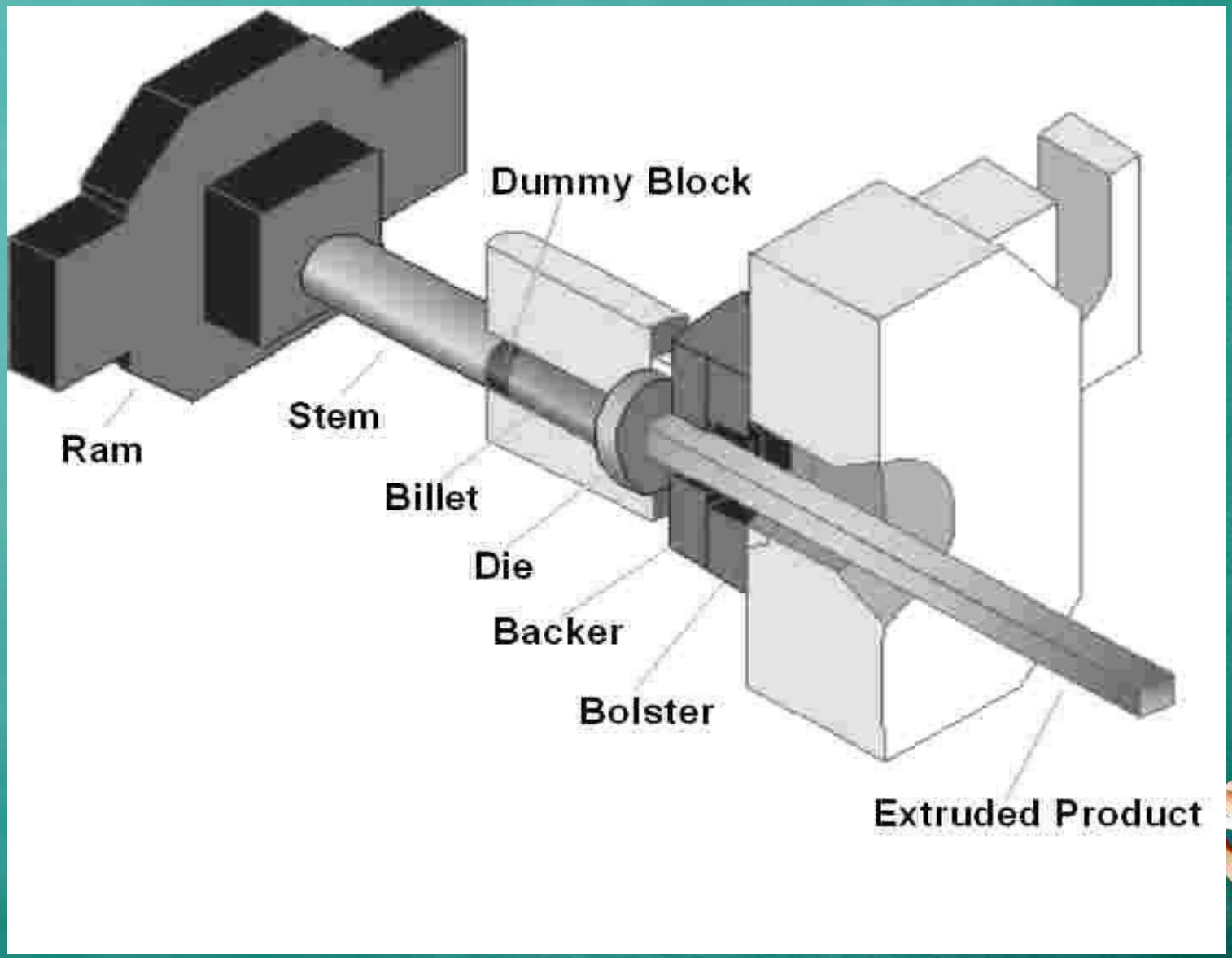
Τιμή της επικινδυνότητας (R)	Βαθμός αμεσότητας λήψης μέτρων
700 - 1000	Άμεση λήψη μέτρων
500 - 700	Λήψη μέτρων σε διάστημα μίας ημέρας
300 - 500	Λήψη μέτρων σε διάστημα ενός μήνα
200 - 300	Λήψη μέτρων σε διάστημα ενός έτους
100 - 200	Μακροπρόθεσμη λήψη μέτρων και παρακολούθηση του συμβάντος
<100	Δεν είναι αναγκαία η άμεση λήψη μέτρων, αλλά η παρακολούθηση του συμβάντος

Εφαρμογή σε Βιομηχανία Διέλασης μετάλλων

έτη: 1999-2004

Εφαρμογή σε Βιομηχανία Διέλασης μετάλλων

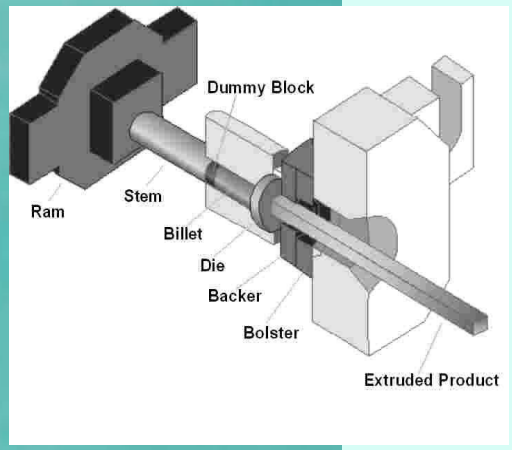
Αρχή της «οδοντόπαστας»



“Μήτρες”

Προφίλ αλουμινίου

Η ΠΑΡΑΓΩΓΙΚΗ ΔΙΑΔΙΚΑΣΙΑ ΔΙΕΛΑΣΗΣ ΑΛΟΥΜΙΝΙΟΥ



Α΄ ΥΛΗ
ΚΟΛΩΝΕΣ ΑΛΟΥΜΙΝΙΟΥ

ΦΟΥΡΝΟΣ ΠΡΟΘΕΡΜΑΝΣΗΣ
ΚΟΛΩΝΩΝ ΑΛΟΥΜΙΝΙΟΥ

ΘΕΡΜΙΚΟ ΨΑΛΙΔΙ ΑΛΟΥΜΙΝΙΟΥ ΣΕ
ΜΠΙΓΙΕΤΕΣ

ΠΡΕΣΑ ΔΙΕΛΑΣΗΣ ΜΠΙΓΙΕΤΩΝ
ΜΕΣΑ ΑΠΌ ΤΙΣ ΜΗΤΡΕΣ

ΕΞΑΓΩΓΗ ΠΡΟΦΙΛ

ΠΑΓΚΟΣ ΨΥΞΗΣ ΠΡΟΦΙΛ

ΤΕΝΤΩΜΑ ΠΡΟΦΙΛ

ΠΡΙΟΝΙ ΚΟΠΗΣ
ΚΟΠΗ ΣΕ ΕΠΙΘΥΜΗΤΑ ΜΗΚΗ

ΦΟΥΡΝΟΣ ΓΗΡΑΝΣΗΣ

ΓΙΑ ΗΛΕΚΤΡΟΣΤΑΤΙΚΗ ΒΑΦΗ

ΣΥΣΚΕΥΑΣΙΑ ΑΒΑΦΩΝ

-**Εντοπισμός & Κατηγοριοποίηση** των σημαντικότερων **πηγών κινδύνου** (col. A)

- Αριθμός των **ανεπιθύμητων συμβάντων** (col. B)

- Οι **συνέπειες** των ανεπιθύμητων συμβάντων (col. C)

-Η **έκθεση** σε πηγές κινδύνου (col. D)

σε βιομηχανία διέλασης αλουμινίου χρησιμοποιώντας πραγματικά δεδομένα ανεπιθύμητων συμβάντων κατά τη διάρκεια του **1999-2004**

Κατηγοριοποίηση ατυχημάτων ή ανεπιθύμητων συμβάντων

βάσει ESAW (European Statistics on Accidents at Work)

- (a) Πτώσεις εργαζομένων (από ύψος, στο ίδιο επίπεδο)
- (b) Κτυπήματα από ολισθήσεις, καταρρεύσεις και συμπίεση ανάμεσα σε αντικείμενα
- (c) Πρόσκρουση σε σταθερά αντικείμενα και κτυπήματα από κινούμενα αντικείμενα
- (d) Άλλες κατηγορίες ατυχημάτων μη ταξινομημένων
- (e) Έκθεση σε ή επαφή με ηλεκτρικό ρεύμα
- (f) Έκθεση σε ή επαφή με ακραίες θερμοκρασίες
- (g) Υπερπροσπάθεια ή κοπιώδεις κινήσεις
- (h) Έκθεση σε ή επαφή με επιβλαβείς ουσίες ή ακτινοβολία

Κατάταξη των σημαντικότερων πηγών κινδύνου

(A)	(B)	(C)	(D)
Description of the most important Hazard Sources	**Number of accidents/ undesirable events (N)**	**Consequences of the undesirable events**	**Exposure to hazard sources**
Injuring due to breaking of aluminum billets'/profiles' parceling hoop	2	Absence from the work >3 days and <3 weeks, and return after full recovery	Presence of damage every 1 week
Exposure/Contact in/with extreme temperatures (e.g. sizzling aluminum profile)	1	Absence from the work >3 days and <3 weeks, and return after full recovery	Presence of damage every 1 week
Drops (Slumps from height)	4	Permanent slight inefficiency	Presence of damage every 1 month
Squeezing and hits by dropping objects (transported by derricks)	4	Permanent slight inefficiency	Presence of damage every 1 hr
Hand/Leg/Foot Mutilation by saw	2	Absence from the work >3 weeks, and return with health problems	Presence of damage every 8 hr (or 1 working shift)
Hand/Leg/Foot Injuring due to the maintenance of machines	1	Absence from the work >3 weeks, and return with health problems	Presence of damage every 1 week
Impacts on stable objects, hits by moving objects	1	Absence from the work >3 days and <3 weeks, and return after full recovery	Presence of damage every 1 month
Injuring due to the die's loading/ unloading on/from the extrusion press	1	Absence from the work >3 days and <3 weeks, and return after full recovery	Presence of damage every 8 hr (or 1 working shift)
Exposure/Contact in/with electric current (electrocution danger) due to the maintenance of electric systems	1	Absence from the work >3 weeks, and return after full recovery	Presence of damage every 1 month

Frequency-Probability scale, similar to Johnson's scale (1975)

Probability Factor (P)	Description of Undesirable Event	Frequency of events occurring
10	Unavoidable	1 event during a time period of $\Delta t << 10^3$ hr
9	Almost assured	1 event during a time period of $\Delta t < 10^3$ hr
8	Frequent	1 event during a time period of $\Delta t \cong 10^3$ hr
7	Probable	1 event during a time period of $10^3 < \Delta t < 10^4$ hr
6	Probability slightly greater than 50%	1event during a time period of $10^4 < \Delta t < 10^5$ hr
5	Probability 50%	1 event during a time period of $\Delta t \cong 10^5$ hr
4	Probability slightly less than 50%	1 event during a time period of $10^5 < \Delta t < 10^6$ hr
3	Almost improbable (or Remote)	1 event during a time period of $10^6 < \Delta t < 10^7$ hr
2	Improbable	1 event during a time period of $\Delta t \cong 10^7$ hr
1	Impossible	1 event during a time period of $\Delta t > 10^7$ hr

(A)	(B)	(C)	(D)	(E)	(F)
Description of Hazard Sources or Undesirable Events	**Probabi-lity Factor (P)**	**Severity of Harm Factor (S)**	**Frequency Factor (F)**	**Risk Value (R)**	**Immediate Actions**
Injuring due to breaking of aluminum billets'/profiles' parceling hoop	6	4	4	96	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
Exposure/Contact in/with extreme temperatures (e.g. sizzling aluminum profile)	6	4	4	96	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
Drops (Slumps from height)	7	7	3	147	R close to 200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
Squeezing and hits by dropping objects (transported by derricks)	7	7	6	**294**	**300>R>>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year**
Hand/Leg/Foot Mutilation by saw	6	6	5	180	R very close to 200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
Hand/Leg/Foot Injuring due to the maintenance of machines	6	6	4	144	R close to 200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
Impacts on stable objects, hits by moving objects	6	4	3	72	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
Injuring due to the die's loading/ unloading on/from the extrusion press	6	4	5	120	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
Exposure/Contact in/with electric current (electrocution danger) due to the maintenance of electric systems	6	5	3	90	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance

Εφαρμογή στον Κλάδο των κατασκευών

Στοιχεία ατυχημάτων του ΙΚΑ (2002)

(A)	(B)	(C)	(D)	(E)	(F)
Description of Undesirable Event	**Number of Accidents**	**Probability Index (P)**	**Severity of Harm Index (S)**	**Frequency Index (F)**	**Risk Value (R)**
Drops (Slumps from height)	2.141	1,34	10	6,12	81,7
Downfalls (at the same level)	2.561	1,60	8	6,33	80,9
Slips, hits by dropping objects	1.880	1,17	10	5,98	70,1
Impacts on stable objects, hits by moving objects	5.477	3,42	9	7,01	**215,7**
Squeezing	2.501	1,56	9	6,30	88,5
Overworking, hard jobs	501	0,31	7	5,16	11,3
Exposure/Contact in/with extreme temperat.	311	0,19	7	5,04	6,8
Exposure/Contact in/with electric current	58	0,04	10	4,05	1,5
(Exposure/Contact in/with harmful substances or radiation	245	0,15	9	5,00	6,9
Other reasons of accidents	356	0,22	-	5,07	-
Total	**16.031**				

Στοιχεία ατυχημάτων του ΣΕΠΕ (2000- 2003) συνολικά για τον κλάδο των Κατασκευών

(A)	(B)	(C)	(D)	(E)
Year	**Probability Index (P)**	**Severity of Harm Index (S)**	**Frequency Index (F)**	**Risk Value (R)**
2000	5,2	10	4,10	213,2
2001	4,6	10	4,20	193,2
2002	5,0	10	4,20	210,0
2003	5,5	10	4,16	228,8

Τεχνική του Πίνακα Απόφασης
Decision Matrix Risk Assessment (DMRA)

Η επικινδυνότητα παρουσιάζεται σαν ένα φυσικό, μετρήσιμο μέγεθος (R)

$$R = f(P, S, \ldots)$$

R: the Risk

P: the Probability Factor

S: the Severity of Harm Factor

Τεχνική του Πίνακα Απόφασης
Decision Matrix Risk Assessment (DMRA)

Η επικινδυνότητα παρουσιάζεται σαν ένα φυσικό, μετρήσιμο μέγεθος (R)

R= P * S

R: the Risk

P: the Probability Factor

S: the Severity of Harm Factor

Τεχνική του Πίνακα Απόφασης (DMRA)

Ο Πίνακας Επικινδυνότητας ή Πίνακας Απόφασης Επικινδυνότητας

	Συνέπειες (S)				
Πιθανότητα (P)	Ασήμαντες	Ελάχιστες	Μέτριες	Μεγάλες	Σοβαρές
Σχεδόν βέβαιη	Β	Γ	Γ	Δ	Δ
Πιθανή	Β	Β	Γ	Γ	Δ
Δυνατή	Α	Β	Β	Γ	Δ
Σπάνια	Α	Β	Β	Β	Γ
Απίθανη	Α	Α	Β	Β	Γ

Χρωματική κλίμακα διαβάθμισης επικινδυνότητας (4 επίπεδα)

	Αποδεκτό	**Α**
	Αποδεκτό με ελέγχους	**Β**
	Μη επιθυμητό	**Γ**
	Μη αποδεκτό	**Δ**

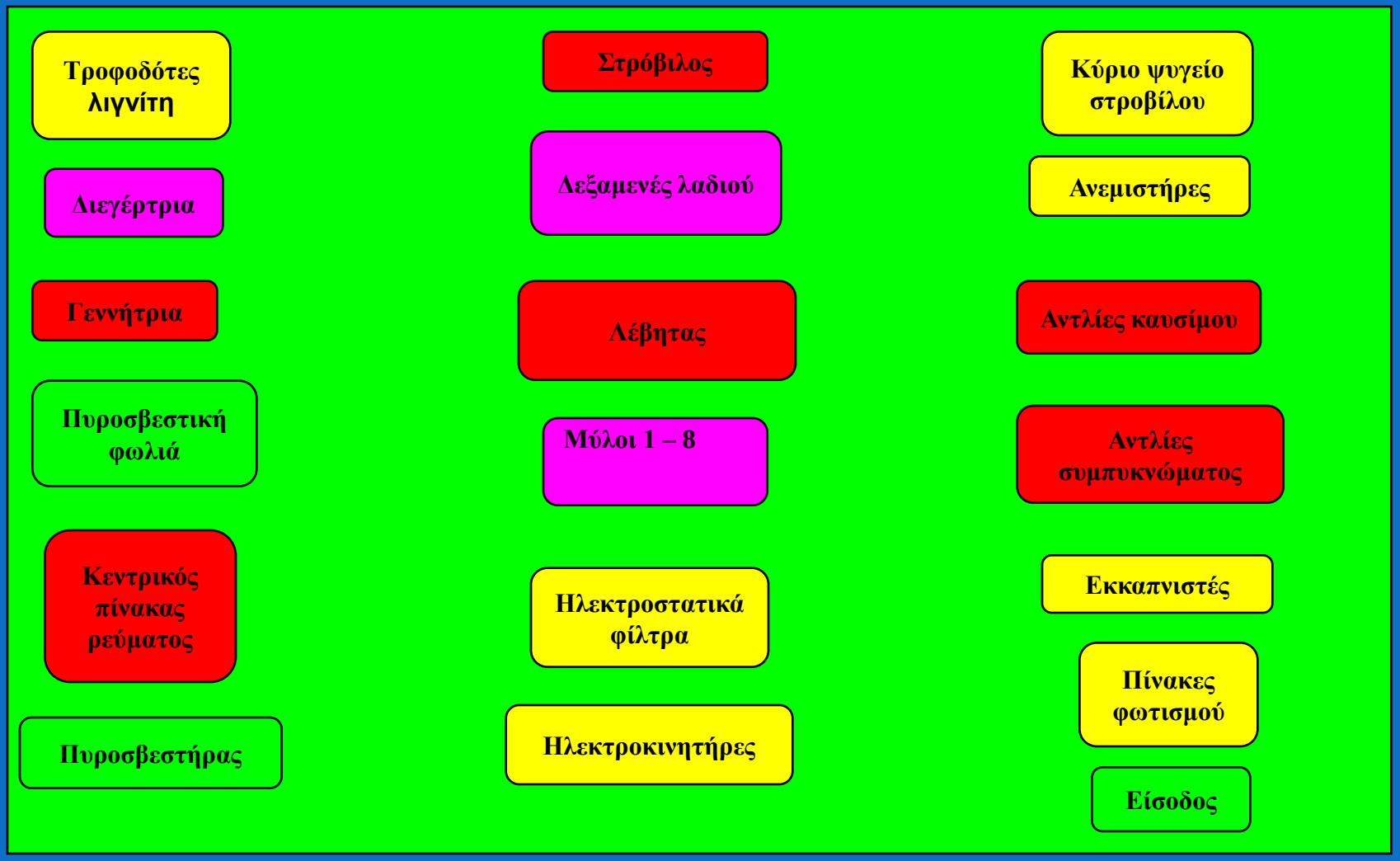
Μηχανήματα στους χώρους εργασίας

1. Στρόβιλος
2. Λέβητας
3. Δεξαμενές Λαδιού
4. Ηλεκτροστατικά Φίλτρα
5. Ηλεκτροκινητήρες
6. Αντλίες Καυσίμου
7. Εκκαπνιστές
8. Αντλίες Συμπυκνώματος
9. Γεννήτρια
10. Διεγέρτρια
11. Κεντρικός Πίνακας Ρεύματος
12. Τροφοδότες Λιγνίτη
13. Κύριο Ψυγείο Στροβίλου

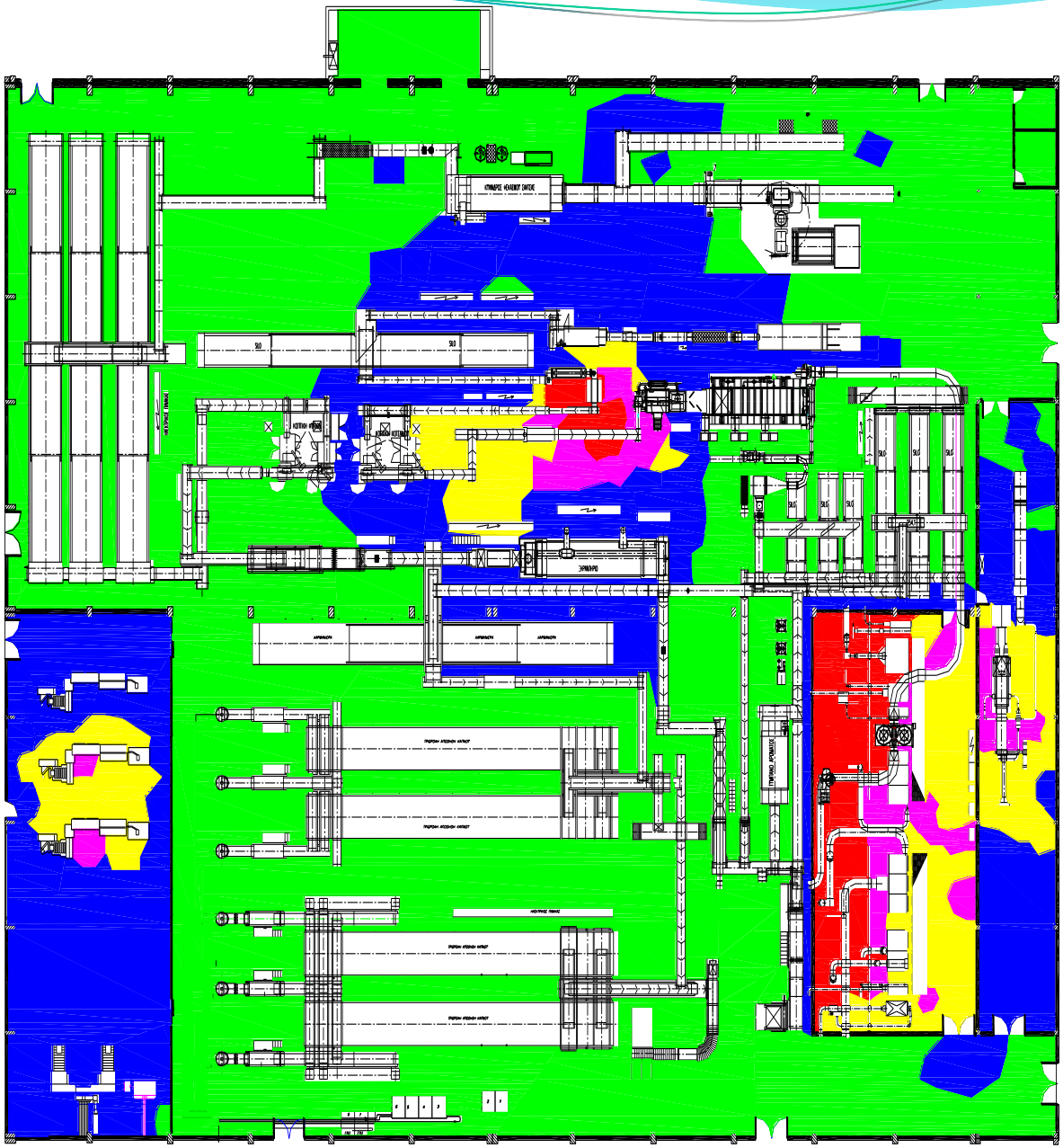
Εφαρμογή του πίνακα απόφασης για τους κινδύνους ανά ειδικότητα στο Μηχανοστάσιο - Λεβητοστάσιο

ΤΕΧΝΙΤΗΣ ΣΤΡΟΒΙΛΟΥ	Κίνδυνος τραυματισμού σχετικός με τις μηχανές Κινούμενα τμήματα Αιχμηρά σημεία	Κόψιμο/ κάταγμα/ακρωτηριασμός/ μωλωπισμός/ Θάνατος	Σοβαρές – πιθανή	Δ
	Πτώση από ύψος	Διάστρεμμα/ κάταγμα/ μωλωπισμός/θάνατος	Σοβαρές – πιθανή	Δ
	Θόρυβος	Προσωρινή απώλεια ακοής	Ελάχιστες - σπάνια	Β
	Ολισθηρό δάπεδο εργασίας	Διάστρεμμα/ κάταγμα/ μωλωπισμός	Μέτριες - πιθανή	Γ
	Βαριά σωματική εργασία	Κόπωση /χρόνια προβλήματα στα πόδια/μέση	Ελάχιστες - δυνατή	Β

Χαρτογράφηση της επικινδυνότητας σε Μηχανοστάσιο - Λεβητοστάσιο με χρωματική κλίμακα σε σχέση με τον κίνδυνο τραυματισμού από μηχανήματα



Χρωματικός χάρτης διαβάθμισης της επικινδυνότητας



Ανάπτυξη μίας νέας υβριδικής-τεχνικής

* **HRAP** (Hybrid Risk Assessment Process)

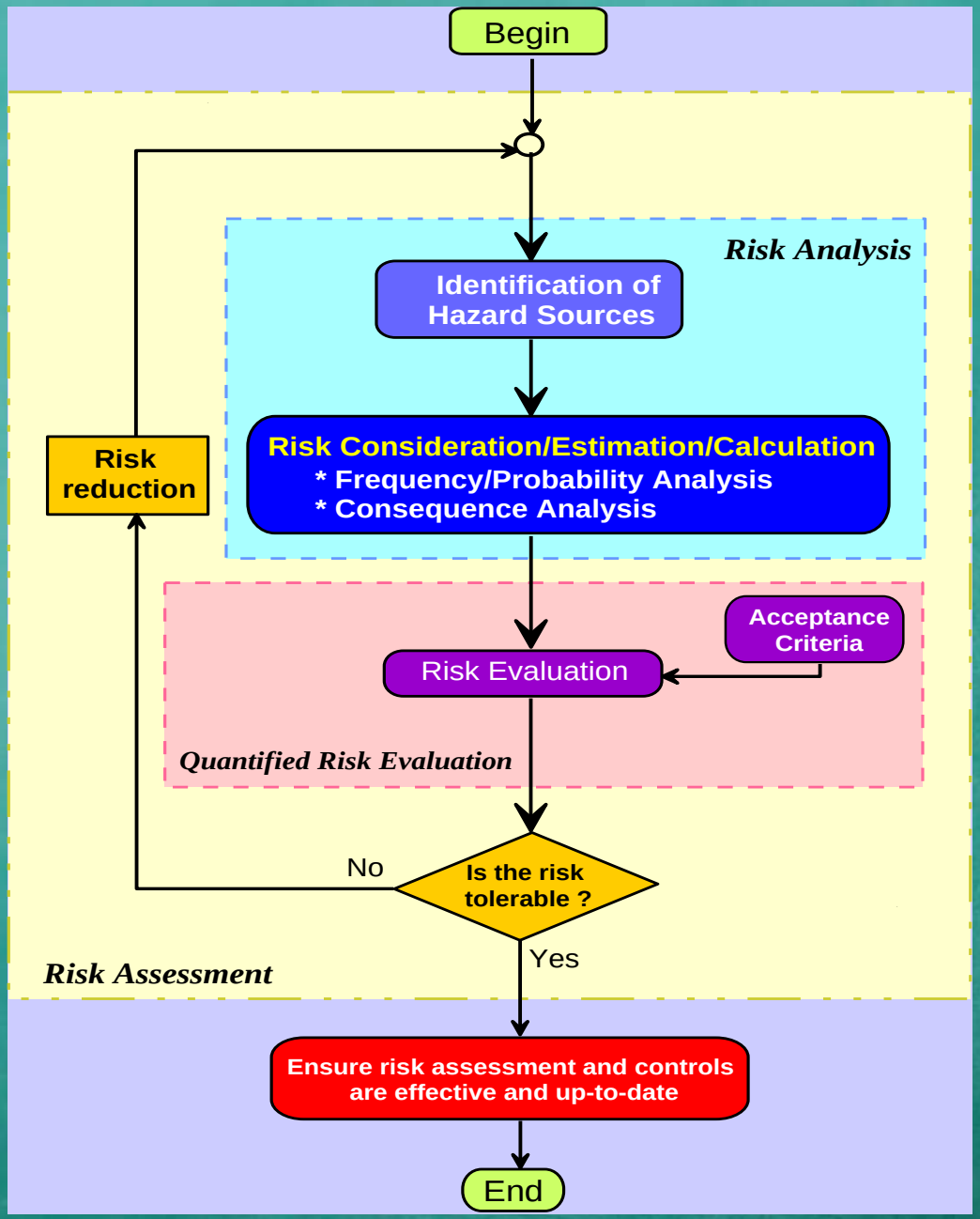
* **Εφαρμόσθηκε** ως μελέτη περίπτωσης (case study), στη:

Δημόσια Επιχείρηση Ηλεκτρισμού (Δ.Ε.Η.)

* Με χρήση στοιχείων ατυχημάτων ή έκθεσης σε πηγές κινδύνου, για την περίοδο 1993-2004

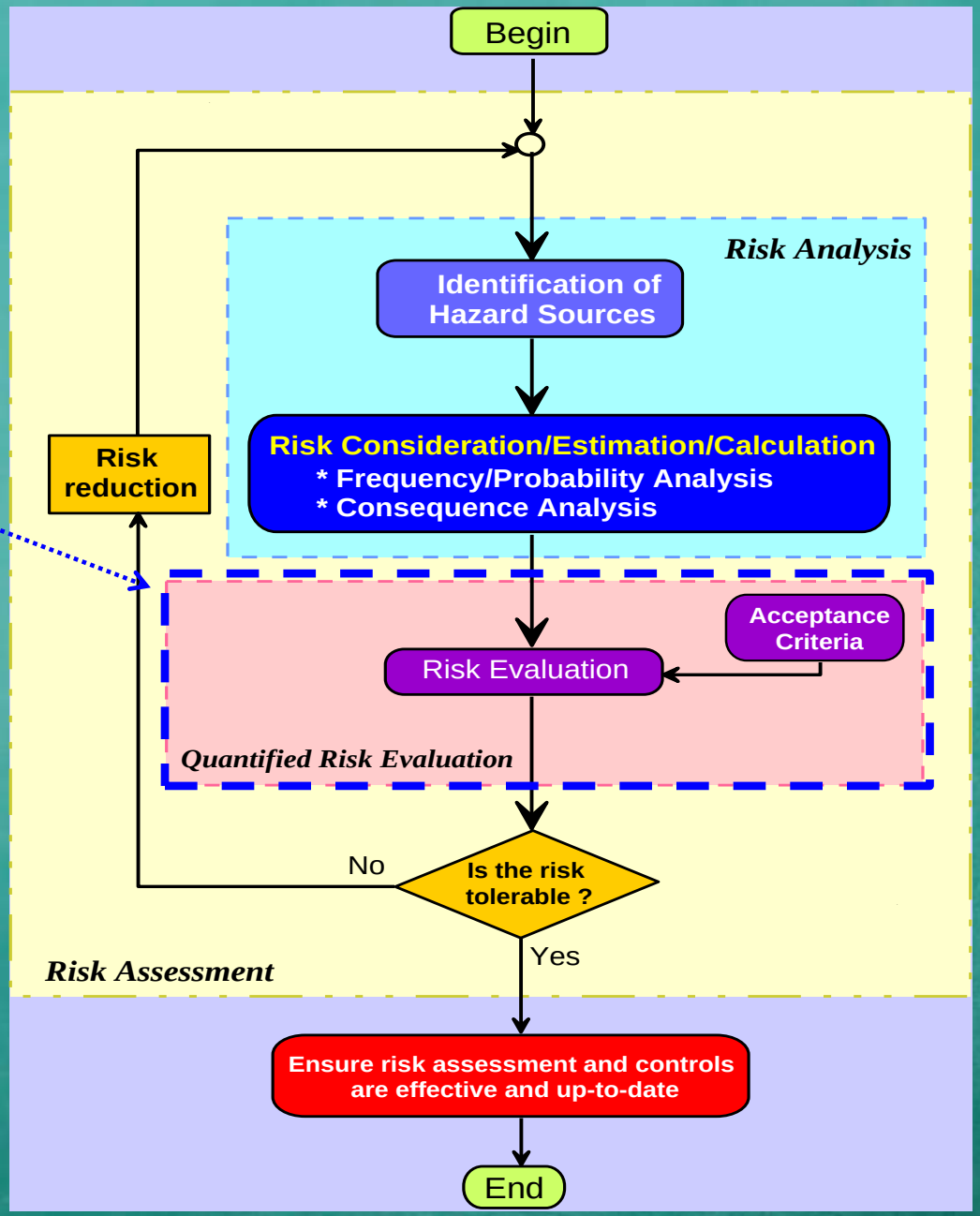
*(**J.LPPI:** Marhavilas et al. 2008b; 2011b)*

HRAP as a part of the risk management process

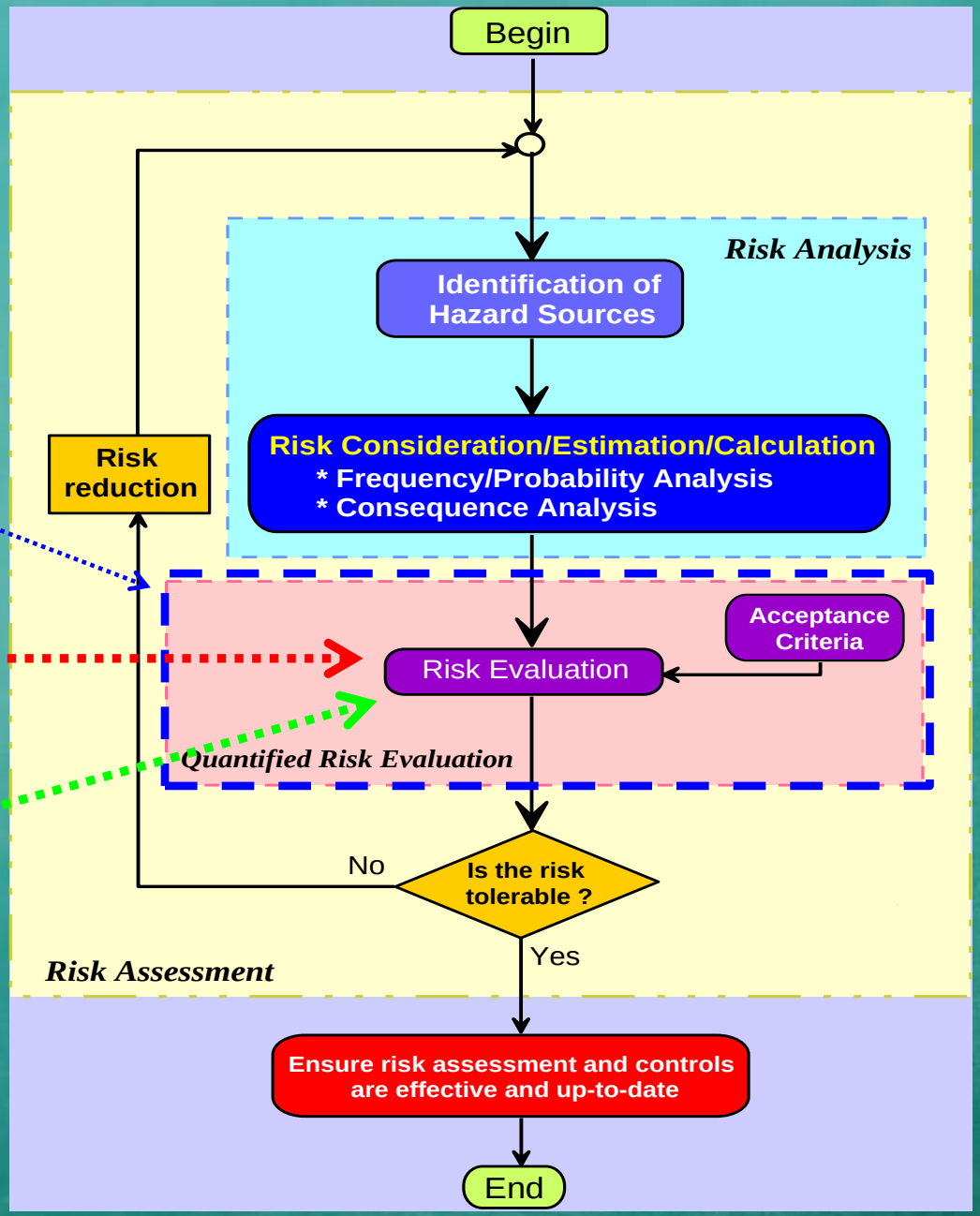


HRAP as a part of the risk management process

HRAP



HRAP as a part of the risk management process

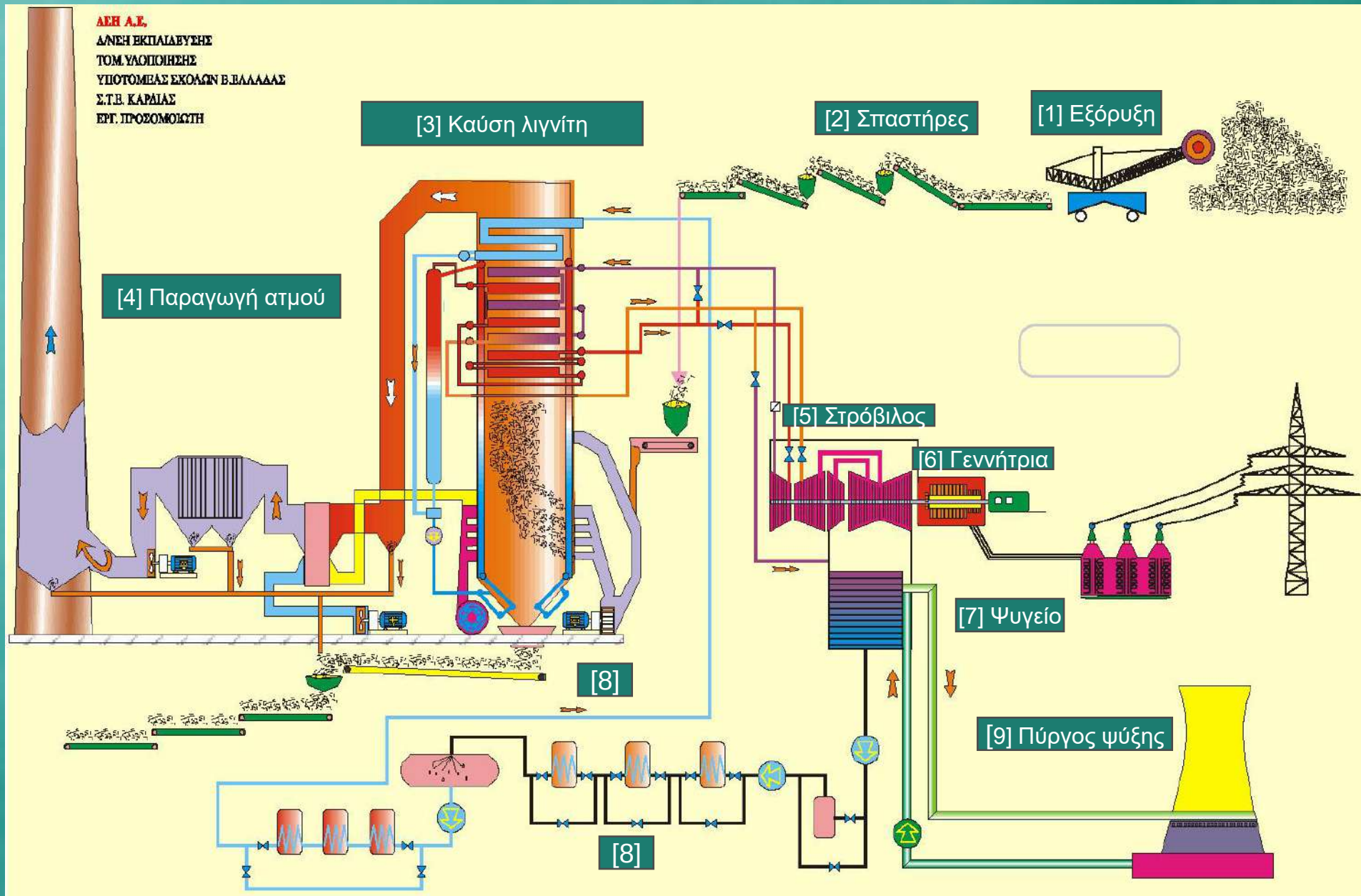


HRAP

PRAT

DMRA

Παραγωγή ηλεκτρικής ενέργειας σε Ατμοηλεκτρικού Σταθμού



Παραγωγή ηλεκτρικής ενέργειας σε Ατμοηλεκτρικού Σταθμού

1. Συλλογή πρώτης ύλης – καυσίμου (λιγνίτης)
2. Επεξεργασία λιγνίτη
3. Εισαγωγή και καύση του λιγνίτη στον Λέβητα
4. Δημιουργία ατμού στην εστία του Λέβητα
5. Έξοδος και πτώση του ατμού με μεγάλη πίεση σε ατμοστρόβιλο
6. Μετατροπή της μηχανικής ενέργειας του στροβίλου σε ηλεκτρική μέσω ηλεκτρογεννήτριας
7. Επιστροφή του ατμού στο Ψυγείο και μετατροπή του πάλι σε νερό
8. Συλλογή των καυσαερίων (Τεφρολεκάνη, Αποθείωση)
9. Απαγωγή εναπομείναντων καυσαερίων στον πύργο ψύξης και μεταφορά στον περιβάλλον

LIGNITE FIELD
(1)

LIGNITE SMASHING
(2)

TRANSPORT/STORAGE
TO BOILER
(3)

WATER PUMPING
(8)

LIGNITE COMBUSTION
(4)

ASH COLLECTION
(5)

ELABORATION
(deionization, desalination)
(9)

STEAM CREATION
(7)

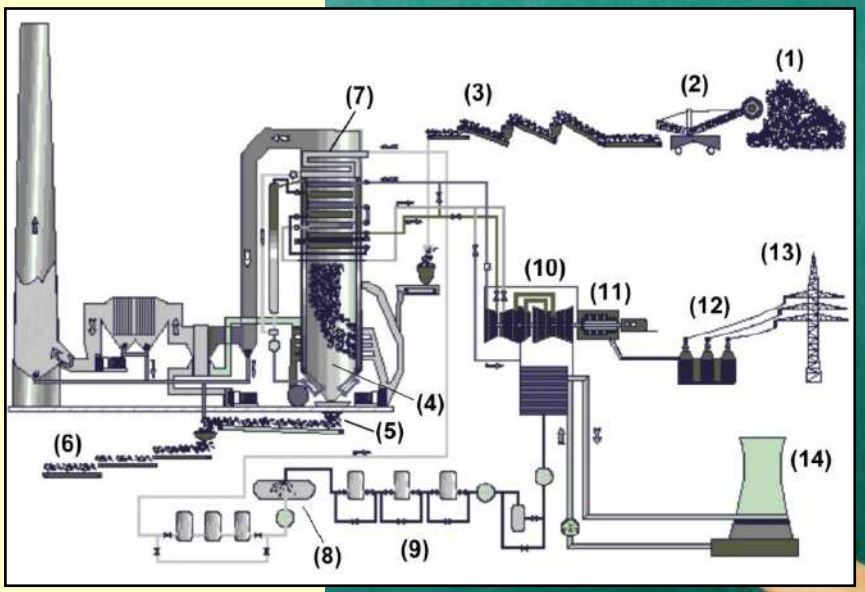
ASH DEPOSIT
(6)

TURBINE MOTION
(10)

GENERATOR MOTION
(11)

ELECTRIC POWER
PRODUCTION
(12)

TRANSFER THROUGH THE
ELECTRICITY NETWORK
(13)



Accident Analysis

ACTIVITY SECTOR (A.C.)	Number of accidents per working-year *[N/wyr]*												Total accidents per A.C. $(N_{total})_{AC}$	Normalized accidents per A.C. & per wyr $[N/wyr]_{AC}$	*Accidents percen-tage* (%)
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**			
MINES	153	173	168	149	84	66	63	69	84	100	69	60	1238	103.17	30.6
GENERATION	91	75	90	71	65	76	67	60	73	64	63	58	853	71.08	21.1
TRANSMISSION	19	16	20	9	18	12	15	14	17	18	13	4	175	14.58	4.3
DISTRIBUTION	149	172	140	144	144	150	115	130	119	117	112	108	1600	133.33	39.5
OTHER	18	9	16	18	14	13	9	16	13	15	17	22	180	15.00	4.5
TOTAL	**430**	**445**	**434**	**391**	**325**	**317**	**269**	**289**	**306**	**314**	**274**	**252**	**4046**	337.17	**100.0**

Year	Number of Employees	Man-working hours *[hrs/yr]*	Number of fatal accidents	FAFR per 10^8 man-hrs
1993	30816	269,948,160.00	7	2.59
1994	32706	286,504,560.00	2	0.70
1995	34805	304,891,800.00	6	1.97
1996	34822	305,040,720.00	10	3.28
1997	34360	300,993,600.00	7	2.33
1998	33784	295,947,840.00	7	2.37
1999	33139	290,297,640.00	6	2.07
2000	32184	281,931,840.00	8	2.84
2001	31659	277,332,840.00	3	1.08
2002	29701	260,180,760.00	14	5.38
2003	29065	254,609,400.00	6	2.36
2004	28429	249,038,040.00	5	2.01
Entire period 1993-2004		**$3.38 \cdot 10^9$**	**81**	**2.40**

Fatal Accident Frequency Rate

France 8.5,

Germany 5,

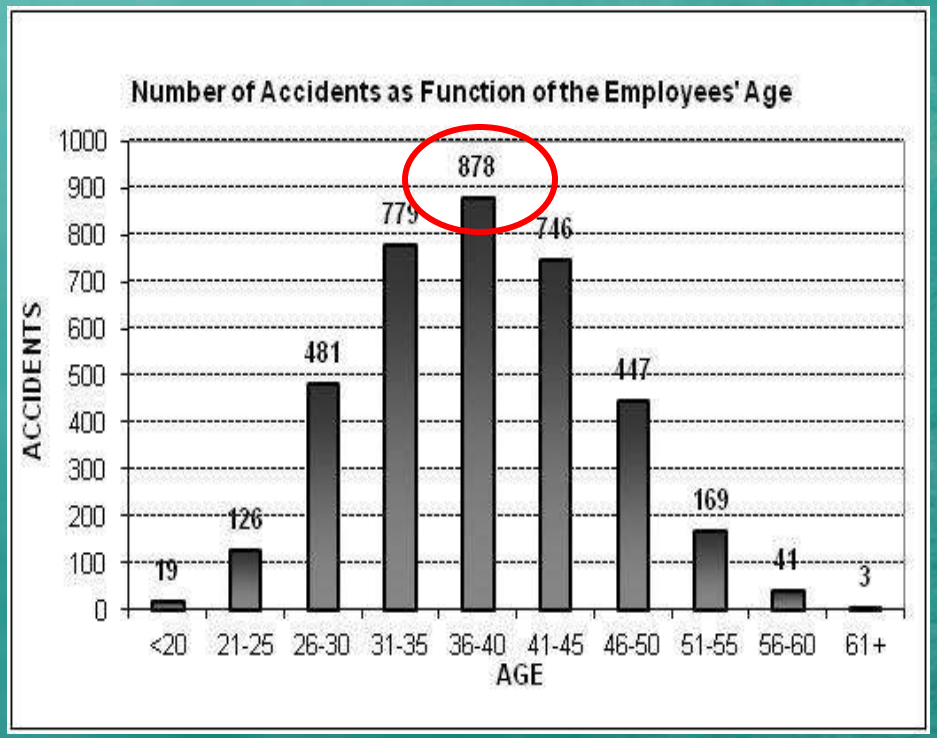
USA 5, UK 4

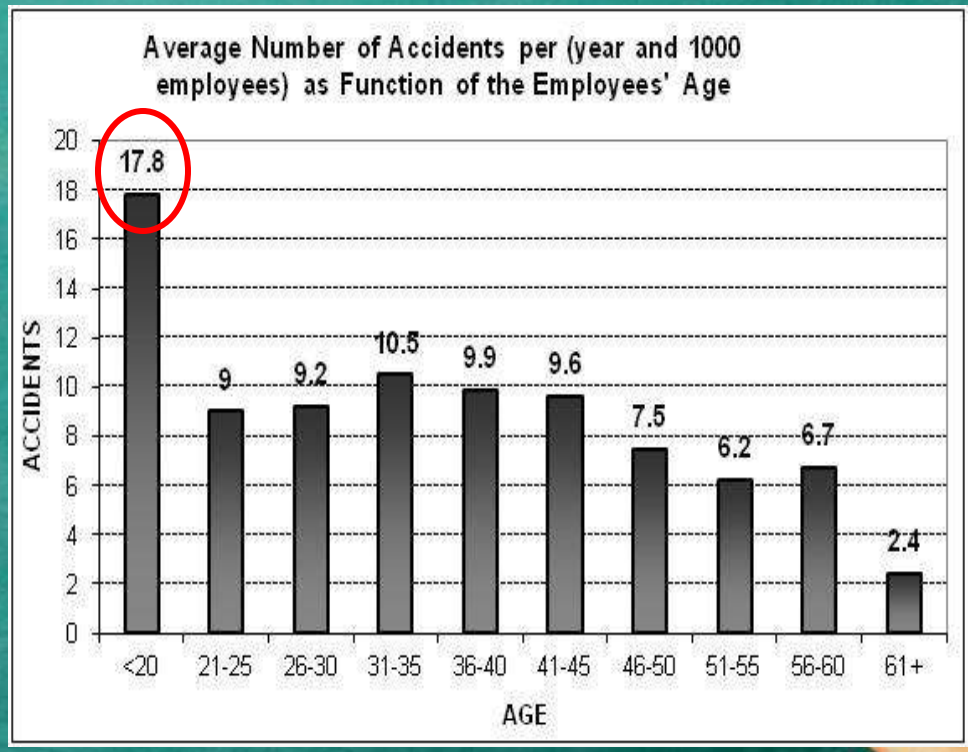
(ISPL, 2011)

ACTIVITY SECTOR (A.C.)	Number of fatal accidents	FAFR per 10^8 man-hrs
MINES	16	2.37
GENERATION	16	2.37
TRANSMISSION	7	1.04
DISTRIBUTION	37	5.48
OTHER	5	0.74
Whole set of PPC's activity sectors	**81**	**2.40**

AGE

AGE	Number of accidents per working-year *[N/wyr]*												Total accidents per age (1993-2004)	Average of Accidents per (year,age and 1000 employees)
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004		
<20	3	2	1	5	4	1	2	0	1	0	0	0	19	17,8
21-25	16	28	28	19	9	7	3	3	8	3	1	1	126	9,0
26-30	59	71	74	62	59	47	27	27	34	13	5	3	481	9,2
31-35	105	113	104	89	58	64	62	52	55	32	25	20	779	10,5
36-40	121	101	99	78	76	68	68	68	75	51	39	34	878	9,9
41-45	63	69	69	67	61	63	62	75	70	63	49	35	746	9,6
46-50	39	41	39	44	35	44	30	35	41	37	30	32	447	7,5
51-55	13	17	9	13	14	15	18	16	15	15	12	12	169	6,2
56-60	4	3	6	5	3	1	2	4	6	3	2	2	41	6,7
>61	0	0	0	0	0	1	0	1	1	0	0	0	3	2,4
Totals	423	445	429	382	319	311	274	281	306	217	163	139	**3689**	





Type of Hazard Sources

Type of Hazard Sources	Number of accidents per working-year *[N/wyr]*												Total	*Accid. percen-tage (%)*
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**		
EMPLOYEES FALLS	93	119	112	103	75	103	63	69	70	65	72	75	1019	31.3
HITS BY DROPPING OBJECTS	49	41	28	25	20	23	8	22	19	13	15	12	275	8.4
IMPACTS ON STABLE OBJECTS	119	131	105	87	60	69	66	62	66	52	45	27	889	27.3
SQUEEZING	53	35	35	40	32	19	19	16	21	16	12	10	308	9.5
EXTREME EFFORT	19	18	11	12	10	7	1	3	4	5	4	3	97	3.0
EXPOSURE TO NATURAL FACTORS	8	14	12	17	4	12	6	9	7	6	6	7	108	3.3
EXPOSURE TO ELECTRICITY	23	21	17	17	22	21	17	23	17	12	10	8	208	6.4
EXPOSURE TO CHEMICALS OR RADIATION	4	2	3	6	4	3	7	2	1	2	1	0	35	1.1
ANIMAL BITES	10	5	5	6	5	3	7	5	6	3	2	1	58	1.8
OTHER	22	25	13	23	21	9	23	68	23	12	12	11	262	8.0
TOTAL	**400**	**411**	**341**	**336**	**253**	**269**	**217**	**279**	**234**	**186**	**179**	**154**	**3259**	**100.0**

Body Part

Body Part	Number of accidents per working-year *[N/wyr]*													Total	*(%)*
	1993	**1994**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**		
HEAD	74	98	98	70	65	41	35	48	42	33	25	23	19	671	18.8
NECK	2	4	4	4	4	4	2	9	3	4	2	3	3	48	1.3
BODY	31	46	46	23	41	21	16	19	20	21	17	12	9	322	9.0
ARMS	140	126	126	124	120	100	86	55	79	67	70	65	60	1218	34.0
LEGS	121	141	141	105	80	74	92	60	57	45	49	55	64	1084	30.3
INJURY ON MULTIPLE PARTS	13	27	27	12	14	7	9	7	61	31	12	10	7	237	6.6
TOTAL	**381**	**442**	**442**	**338**	**324**	**247**	**240**	**198**	**262**	**201**	**175**	**168**	**162**	**3580**	**100.0**

(A)	(B)	(C)	(D)
Hazard Sources	**Information recorded in the accident-book of PPC**	**Consequences of the undesirable events**	**Severity Index (S)**
SLIPPING	2 months out of work	Absence from the work> 3 weeks, and return with health problems	6
NARROW (CONSTRAINED) SPACE	Respiratory problems	Permanent slight inefficiency	7
MOVEMENT OBSTRUCTION	1 month absence	Absence from the work> 3 weeks, and return after full recovery	5
ALTITUDE CONDITIONS WORK	3-week backboard use	Absence from the work> 3 weeks, and return with health problems	6
NOISE	Earplug use	Permanent serious inefficiency	8
HYDRAULICS UNDER PRESSURE	Serious injury	Permanent serious inefficiency	8
SHARPNESS	Scratch, injury	Permanent slight inefficiency	7
HEAVY WEIGHT LIFTING	Squashing	Death	10
HASTE	Fracture of legs	Permanent slight inefficiency	7
VEHICLE MOTION	Fatality	Death	10
TRAFFIC	Vehicular accident	Death	10
FLOATING FUMES, DUST	Neural problems	Permanent slight inefficiency	7
RADIATION	Neural problems	Absence from the work> 3 weeks, and return with health problems	6
POLLUTION FACTORS	Skin diseases	Absence from the work> 3 weeks, and return after full recovery	5
INSUFFICIENT LIGHT	Hand scratch, 1 week out of work	Absence from the work> 3 days, and <3 weeks, and return after full recovery	4
EXTREME TEMPERATURES	First degree burn	Absence from the work> 3days and <3weeks and return after full recovery	4
LEAKAGES CAUSING FIRES	Death from burn	Death	10
LIGNITE SELF-IGNITION	Death from fumes	Death	10
INTENSE WORK-TIREDNESS /INSUFFICIENT GUIDANCE	Absence from the work> 3 weeks	Absence from the work> 3 weeks, and return after full recovery	5
ELECTRICITY	Electrocution	Death	10
MATERIAL EMISSION	Injuring, 2nd level burn	Permanent slight inefficiency	7
INSUFFICIENT VENTILATION	Vapours	Absence from the work> 3 weeks, and return after full recovery	5
STRETCH	Contusions, wounds	Absence from the work> 3 weeks, and return after full recovery	5

Classification of the most important hazard sources at a steam power plant of PPC (1993-2004)

PRAT

Frequency Index F at a steam power plant of PPC (1993-2004)

(A)	(B)	(C)	(D)
Hazard Sources	**Information recorded in the accident-book of PPC**	**Frequency of Exposure to hazard sources (according to Table 8)**	**Frequency Index (F)**
SLIPPING	Exposure every 2 hrs	Presence of a potential hazard source every 1 hr	6
NARROW (CONSTRAINED) SPACE	Exposure 2 times per week	Presence of a potential hazard source every 1 week	4
MOVEMENT OBSTRUCTION	Exposure once (1) per day	Presence of a potential hazard source every 8 hr	5
ALTITUDE CONDITIONS WORKING	Exposure every 1 min	Presence of a potential hazard source every 1 min	8
NOISE	Exposure once (1) per relay	Presence of a potential hazard source every 8 hr	5
HYDRAULICS UNDER PRESSURE	Exposure once (1) per relay	Presence of a potential hazard source every 8 hr	5
SHARPNESS	Exposure once (1) per relay	Presence of a potential hazard source every 8 hr	5
HEAVY WEIGHT LIFTING	10 times/day weight lifting	Presence of a potential hazard source every 1 hr	6
HASTE	Exposure every 1 hr	Presence of a potential hazard source every 1 hr	6
VEHICLE MOTION	Exposure every 20min	Presence of a potential hazard source every 30 min	7
TRAFFIC	Exposure once (1) per relay	Presence of a potential hazard source every 8 hr	5
FLOATING FUMES, DUST	Exposure every <40 min	Presence of a potential hazard source every 30 min	7
RADIATION	Exposure every 1 hr	Presence of a potential hazard source every 1 hr	6
POLLUTION FACTORS	Exposure 3 times per week	Presence of a potential hazard source every 1 week	4
INSUFFICIENT LIGHT	Work done every 30-40 min	Presence of a potential hazard source every 30 min	7
EXTREME TEMPERATURES	Work done every 30-40 min	Presence of a potential hazard source every 30 min	7
LEAKAGES CAUSING FIRES	Exposure once (1) per relay	Presence of a potential hazard source every 8 hr	5
LIGNITE SELF-IGNITION	1 fire per day	Presence of a potential hazard source every 8 hr	5
INTENSE WORK-TIREDNESS /INSUFFICIENT GUIDANCE	Repeated work:10 times/ day	Presence of a potential hazard source every 1 hr	6
ELECTRICITY	Presence every 1 min	Presence of a potential hazard source every 1 min	8
MATERIAL EMISSION	3 times per day	Presence of a potential hazard source every 8 hr	5
INSUFFICIENT VENTILATION	Repeated work:12 times/ day	Presence of a potential hazard source every 1 hr	6
STRETCH	3 times per month	Presence of a potential hazard source every 1 week	4

PRAT

(A) Hazard Sources	(B) Severity (S)	(C) Frequency Index (F)	(D) Likelihood Index (P)	(E) Risk Value (R)	(F) Immediate Actions
SLIPPING	6	6	6.48	233.28	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
NARROW (CONSTRAINED) SPACE	7	4	3.48	97.44	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
MOVEMENT OBSTRUCTION	5	5	6.48	162.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
ALTITUDE CONDITIONS WORKING	6	8	6.35	304.80	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
NOISE	8	5	8.54	**341.60**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
HYDRAULICS UNDER PRESSURE	8	5	3.70	148.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
SHARPNESS	7	5	7.33	256.55	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
HEAVY WEIGHT LIFTING	10	6	6.48	**388.80**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
HASTE	7	6	7.25	304.50	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
VEHICLE MOTION	10	7	3.43	240.10	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
TRAFFIC	10	5	3.43	171.50	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
FLOATING FUMES, DUST	7	7	6.35	311.15	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
RADIATION	6	6	4.44	159.84	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
POLLUTION FACTORS	5	4	6.48	129.60	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
INSUFFICIENT LIGHT	4	7	6.48	181.44	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
EXTREME TEMPERATURES	4	7	6.48	181.44	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
LEAKAGES CAUSING FIRES	10	5	6.79	339.50	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
LIGNITE SELF-IGNITION	10	5	8.74	**437.00**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
INTENSE WORK-TIREDNESS /INSUFFICIENT GUIDANCE	5	6	4.36	130.80	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
ELECTRICITY	10	8	6.48	518.40	700>R>500 ⇒ Required actions (or suppressive measures) are essential earlier than 1 day
MATERIAL EMISSION	7	5	6.48	226.80	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
INSUFFICIENT VENTILATION	5	6	5.61	168.30	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
STRETCH	5	4	6.35	127.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance

* Risk value R

* required actions

* PRAT technique using real data of undesirable events and accidents (1993-2004)

(A) Hazard Sources	(B) Severity (S)	(C) Frequency Index (F)	(D) Likelihood Index (P)	(E) Risk Value (R)	(F) Immediate Actions
SLIPPING	6	6	6.48	233.28	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
NARROW (CONSTRAINED) SPACE	7	4	3.48	97.44	R<<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
MOVEMENT OBSTRUCTION	5	5	6.48	162.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
ALTITUDE CONDITIONS WORKING	6	8	6.35	304.80	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
NOISE	8	5	8.54	**341.60**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
HYDRAULICS UNDER PRESSURE	8	5	3.70	148.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
SHARPNESS	7	5	7.33	256.55	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
HEAVY WEIGHT LIFTING	10	6	6.48	**388.80**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
HASTE	7	6	7.25	364.50	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
VEHICLE MOTION	10	7	3.43	240.10	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
TRAFFIC	10	5	3.43	171.50	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
FLOATING FUMES, DUST	7	7	6.35	311.15	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
RADIATION	6	6	4.44	159.84	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
POLLUTION FACTORS	5	4	6.48	129.60	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
INSUFFICIENT LIGHT	4	7	6.48	181.44	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
EXTREME TEMPERATURES	4	7	6.48	181.44	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
LEAKAGES CAUSING FIRES	10	5	6.79	339.50	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier th… 1 month
LIGNITE SELF-IGNITION	10	5	8.74	**437.00**	500>R>300 ⇒ Required actions (or suppressive measures) are essential earlier than 1 month
INTENSE WORK-TIREDNESS /INSUFFICIENT GUIDANCE	5	6	4.36	130.80	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
ELECTRICITY	10	8	6.48	518.40	700>R>300 … suppressive measures) are essential earlier… 1 day
MATERIAL EMISSION	7	5	6.48	226.80	300>R>200 ⇒ Required actions (or suppressive measures) are essential earlier than 1 year
INSUFFICIENT VENTILATION	5	6	5.61	168.30	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance
STRETCH	5	4	6.35	127.00	R<200 ⇒ Immediate action is not necessary but it is required the event's surveillance

* Risk value R

* required actions

* PRAT technique using real data of undesirable events and accidents (1993-2004)

518.40

Urgent suppressive measures are essential

(J.LPPI: Marhavilas et al. 2008b; 2011b)

• Η εκτιμούμενη τιμή της **επικινδυνότητας**, για ορισμένες πηγές κινδύνου: **R ≥ 500**

(στην κλίμακα 0-1000)

• Το γεγονός αυτό καταδεικνύει την αναγκαιότητα της **λήψης άμεσων μέτρων**, προκειμένου να **υποβαθμιστεί** ο άμεσος κίνδυνος για την εκδήλωση σοβαρού ατυχήματος

*(**J.LPPI:** Marhavilas et al. 2008b; 2011b)*

Decision Matrix Risk Assessment technique

DMRA

Severity of Consequence (C)	Hazard Likelihood ratings (L)									
	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
7	7	14	21	28	35	42	49	56	63	70
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100

The decision-making table (with 6 levels)

Colors & Patterns	Category of risk	Risk Value	Evaluation of tolerability
	Rejectable	$70 \le R_{DM} \le 100$	Unacceptable
	Unacceptable	$50 \le R_{DM} < 70$	
	Objectionable	$30 \le R_{DM} < 50$	Risk that should be reduced
	Undesirable	$16 \le R_{DM} < 30$	
	Acceptable with controls	$7 \le R_{DM} < 16$	Acceptable
	Acceptable	$1 \le R_{DM} < 7$	

The risk matrix

DMRA

Risk Assessment Decisions

(A) Hazard Sources	(B) Severity or Consequence Factor (C)	(C) Likelihood Index (L)	(D) Risk Value (R_{DM})	(E) Risk Assessment Decisions	(F) Immediate Actions
SLIPPING	6	6.48	**38.88**		$30<R_{DM}<50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
NARROW (CONSTRAINED) SPACE	7	3.48	**24.36**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
MOVEMENT OBSTRUCTION	5	6.48	**32.40**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
ALTITUDE CONDITIONS WORKING	6	6.35	**38.10**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
NOISE	8	8.54	**68.32**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HYDRAULICS UNDER PRESSURE	8	3.70	**29.60**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
SHARPNESS	7	7.33	**51.31**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HEAVY WEIGHT LIFTING	10	6.48	**64.80**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HASTE	7	7.25	**50.75**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
VEHICLE MOTION	10	3.43	**34.30**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
TRAFFIC	10	3.43	**34.30**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
FLOATING FUMES, DUST	7	6.35	**44.45**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
RADIATION	6	4.44	**26.64**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
POLLUTION FACTORS	5	6.48	**32.40**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
INSUFFICIENT LIGHT	4	6.48	**25.92**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
EXTREME TEMPERATURES	4	6.48	**25.92**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
LEAKAGES CAUSING FIRES	10	6.79	**67.90**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
LIGNITE SELF-IGNITION	10	8.74	**87.40**		$70< R_{DM} <100 \Rightarrow$ Rejectable. Immediate & urgent actions to eliminate the hazard source, **instantly**
INTENSE WORK-TIREDNESS/INSUFFICIENT GUIDANCE	5	4.36	**21.80**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
ELECTRICITY	10	6.48	**64.80**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
MATERIAL EMISSION	7	6.48	**45.36**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
INSUFFICIENT VENTILATION	5	5.61	**28.05**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
STRETCH	5	6.35	**31.75**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.

DMRA

Risk Assessment Decisions

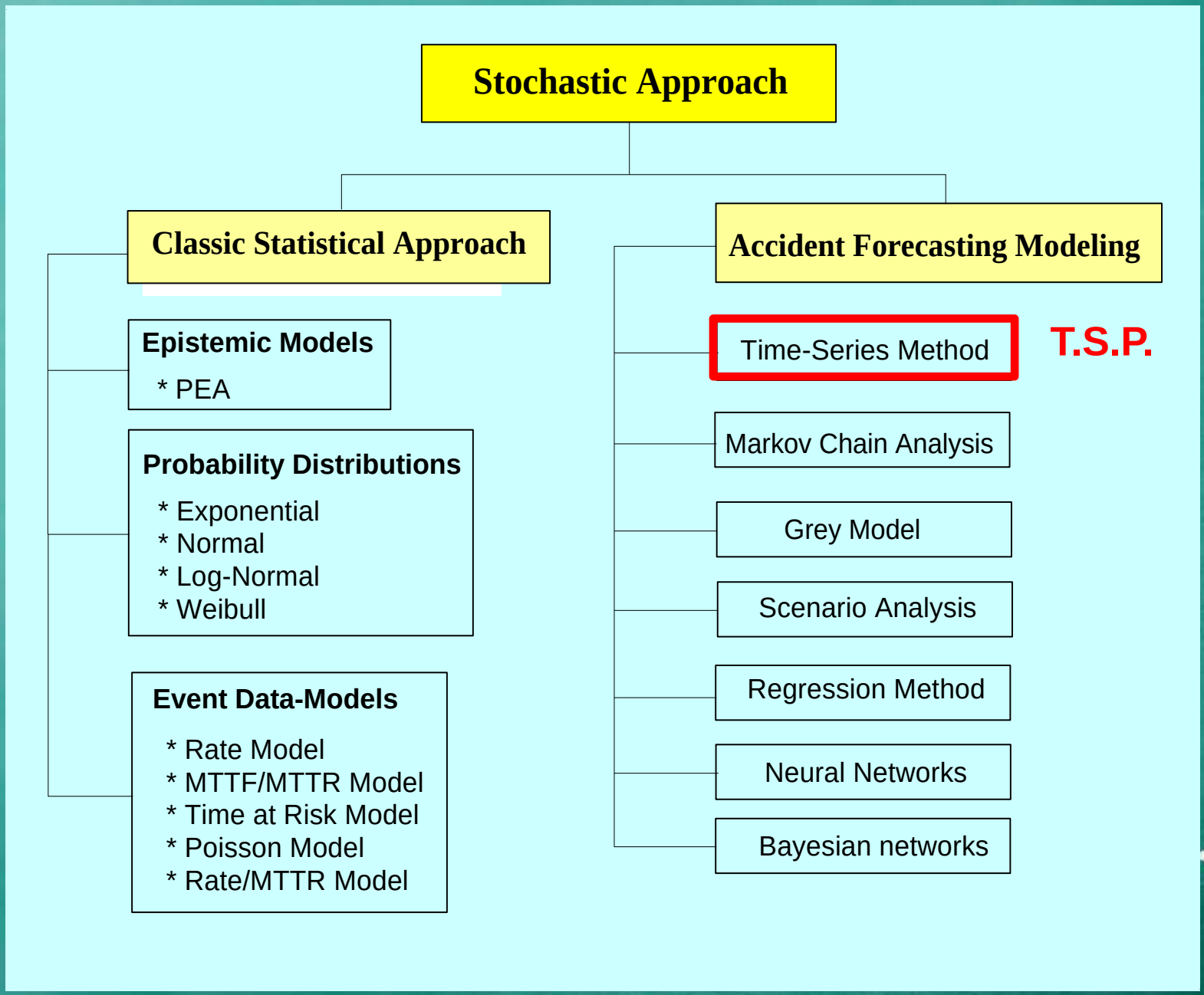
(A)	(B)	(C)	(D)	(E)	(F)
Hazard Sources	**Severity or Consequence Factor (C)**	**Likelihood Index (L)**	**Risk Value (R_{DM})**	**Risk Assessment Decisions**	**Immediate Actions**
SLIPPING	6	6.48	**38.88**		$30<R_{DM}<50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
NARROW (CONSTRAINED) SPACE	7	3.48	**24.36**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
MOVEMENT OBSTRUCTION	5	6.48	**32.40**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
ALTITUDE CONDITIONS WORKING	6	6.35	**38.10**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
NOISE	8	8.54	**68.32**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HYDRAULICS UNDER PRESSURE	8	3.70	**29.60**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
SHARPNESS	7	7.33	**51.31**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HEAVY WEIGHT LIFTING	10	6.48	**64.80**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
HASTE	7	7.25	**50.75**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
VEHICLE MOTION	10	3.43	**34.30**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions t… eliminate the hazard source.
TRAFFIC	10	3.43	**34.30**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required… eliminate the hazard source.
FLOATING FUMES, DUST	7	6.35	**44.45**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Req… eliminate the hazard source.
RADIATION	6	4.44	**26.64**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Req… eliminate the hazard source.
POLLUTION FACTORS	5	6.48	**32.40**		$30< R_{DM} <50 \Rightarrow$ Objectionable. R… eliminate the hazard source.
INSUFFICIENT LIGHT	4	6.48	**25.92**		$16< R_{DM} <30 \Rightarrow$ … eliminate t…
EXTREME TEMPERATURES	4	6.48	**25.92**		…Undesirable. Required … …inate the hazard source.
LEAKAGES CAUSING FIRES	10	6.79	**67.90**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urg… actions to eliminate the hazard source, **instantly**
LIGNITE SELF-IGNITION	10	8.74	**87.40**		$70< R_{DM} <100 \Rightarrow$ Rejectable. Immediate & urgent actions to eliminate the hazard source, **instantly**
INTENSE WORK-TIREDNESS/INSUFFICIENT GUIDANCE	5	4.36	**21.80**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
ELECTRICITY	10	6.48	**64.80**		$50< R_{DM} <70 \Rightarrow$ Unacceptable. Immediate & urgent actions to eliminate the hazard source, **instantly**
MATERIAL EMISSION	7	6.48	**45.36**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.
INSUFFICIENT VENTILATION	5	5.61	**28.05**		$16< R_{DM} <30 \Rightarrow$ Undesirable. Required actions to eliminate the hazard source.
STRETCH	5	6.35	**31.75**		$30< R_{DM} <50 \Rightarrow$ Objectionable. Required actions to eliminate the hazard source.

Rejectable. Immediate & urgent actions to eliminate the hazard source, instantly

Ανάλυση χρονοσειρών R(t)

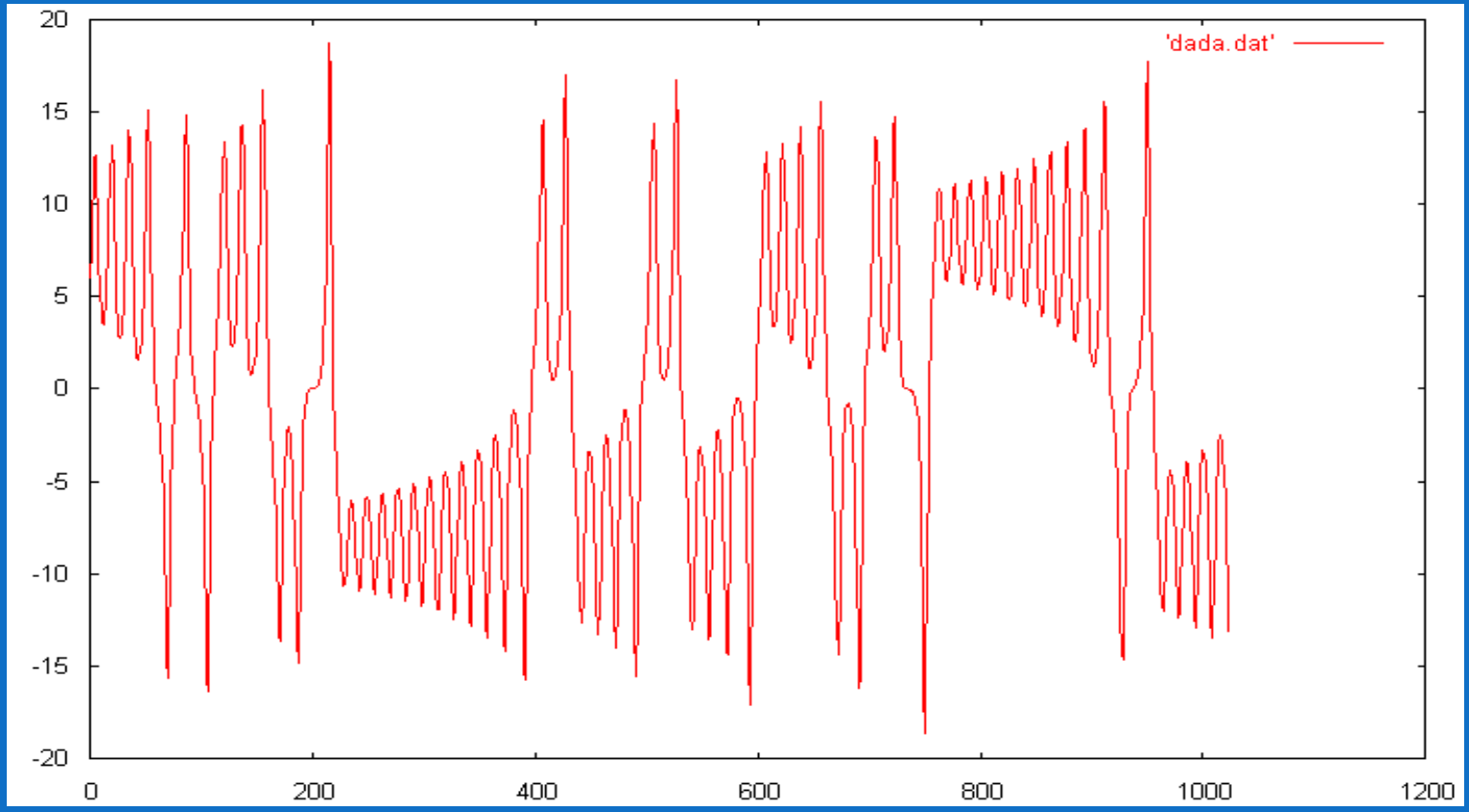
T.S.P.

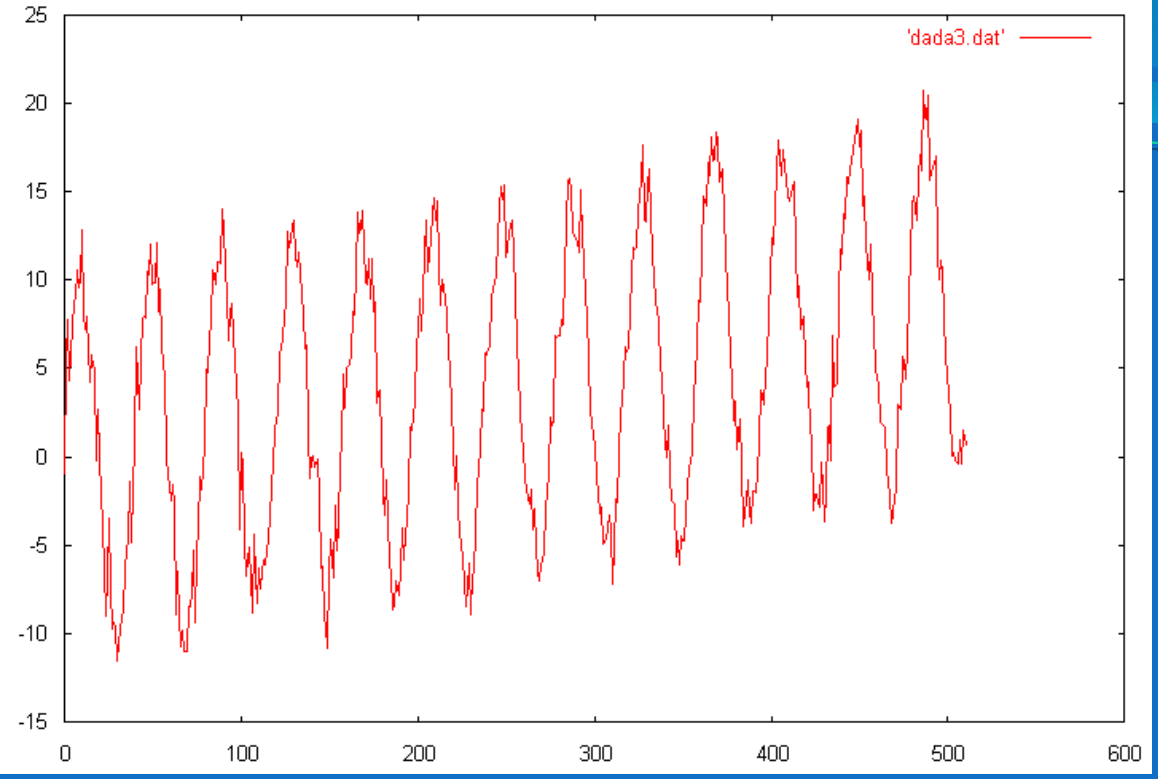
Πιθανοκρατικές Τεχνικές



Ανάλυση χρονοσειρών R(t)

Χρονοσειρά: Ακολουθία παρατηρήσεων σε διαφορετικά χρονικά σημεία

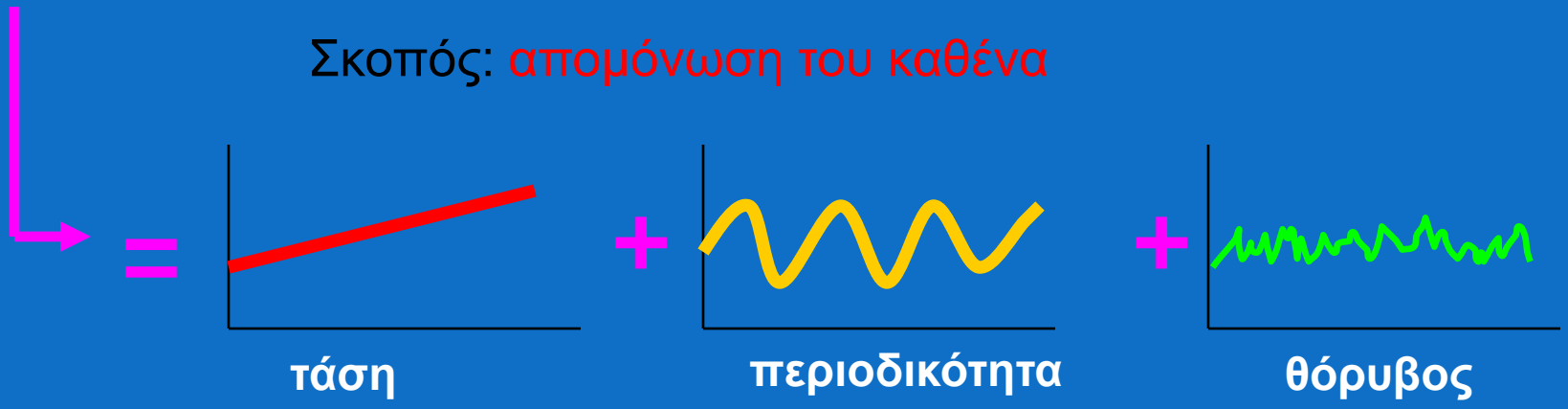




συνυπάρχουν 3 χαρακτηριστικά:

- **τάση (κλίση)**,
- **περιοδικότητα**,
- **θόρυβος**

Σκοπός: απομόνωση του καθένα

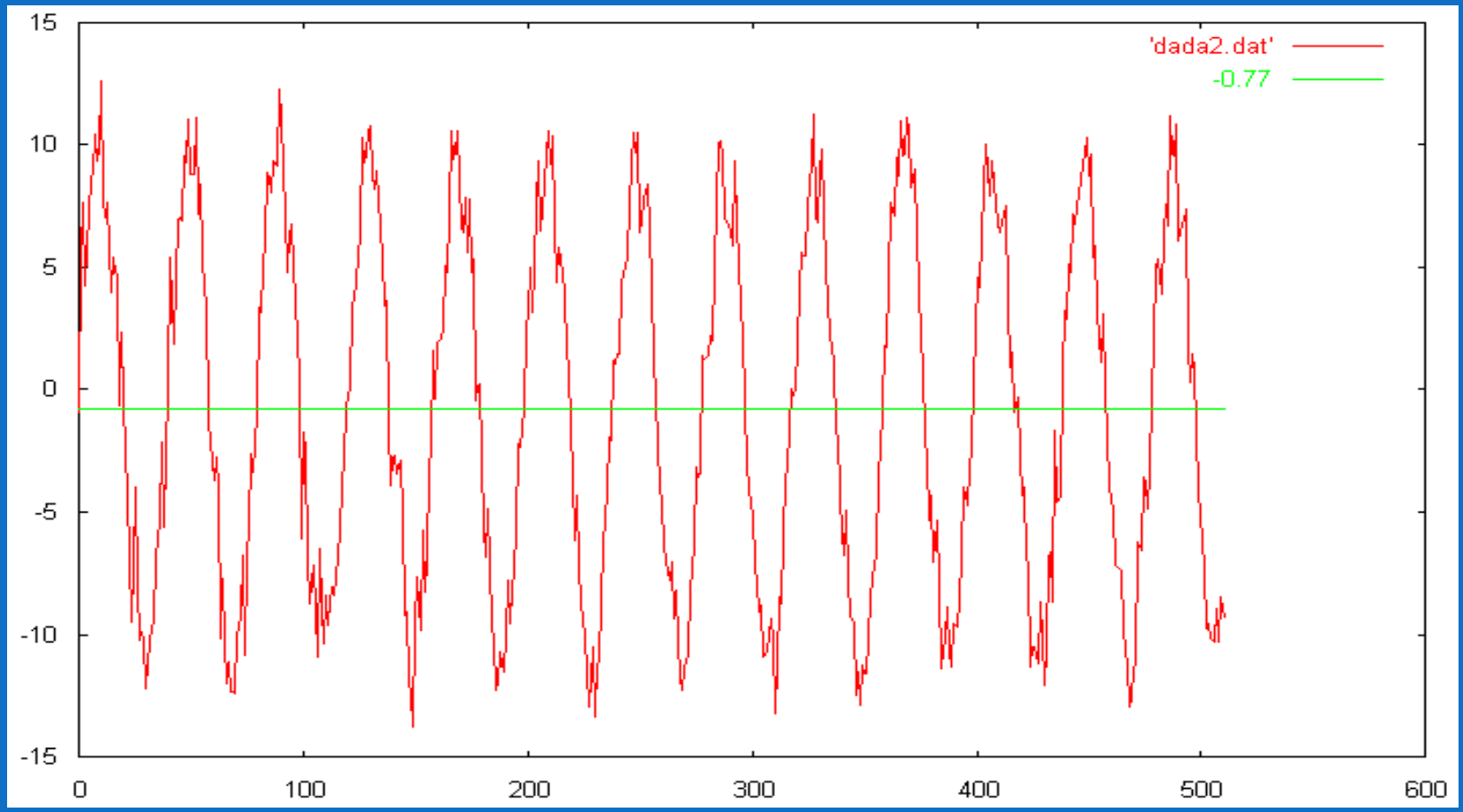


Μέθοδος της ανάλυσης (decomposition)

- **βασικός σκοπός:** να διαχωρίσουμε και να απομονώσουμε τα διάφορα χαρακτηριστικά μιας χρονοσειράς:
  κυρίως τα μη-στάσιμα από τα στάσιμα χαρακτηριστικά
- **Εργαλεία:** εξομάλυνση (smoothing), προσαρμογή (fitting), αφαίρεση, παίρνουμε τη διαφορά …

Ανάλυση χρονοσειρών R(t)

Στάσιμη χρονοσειρά: Χωρίς κλίση



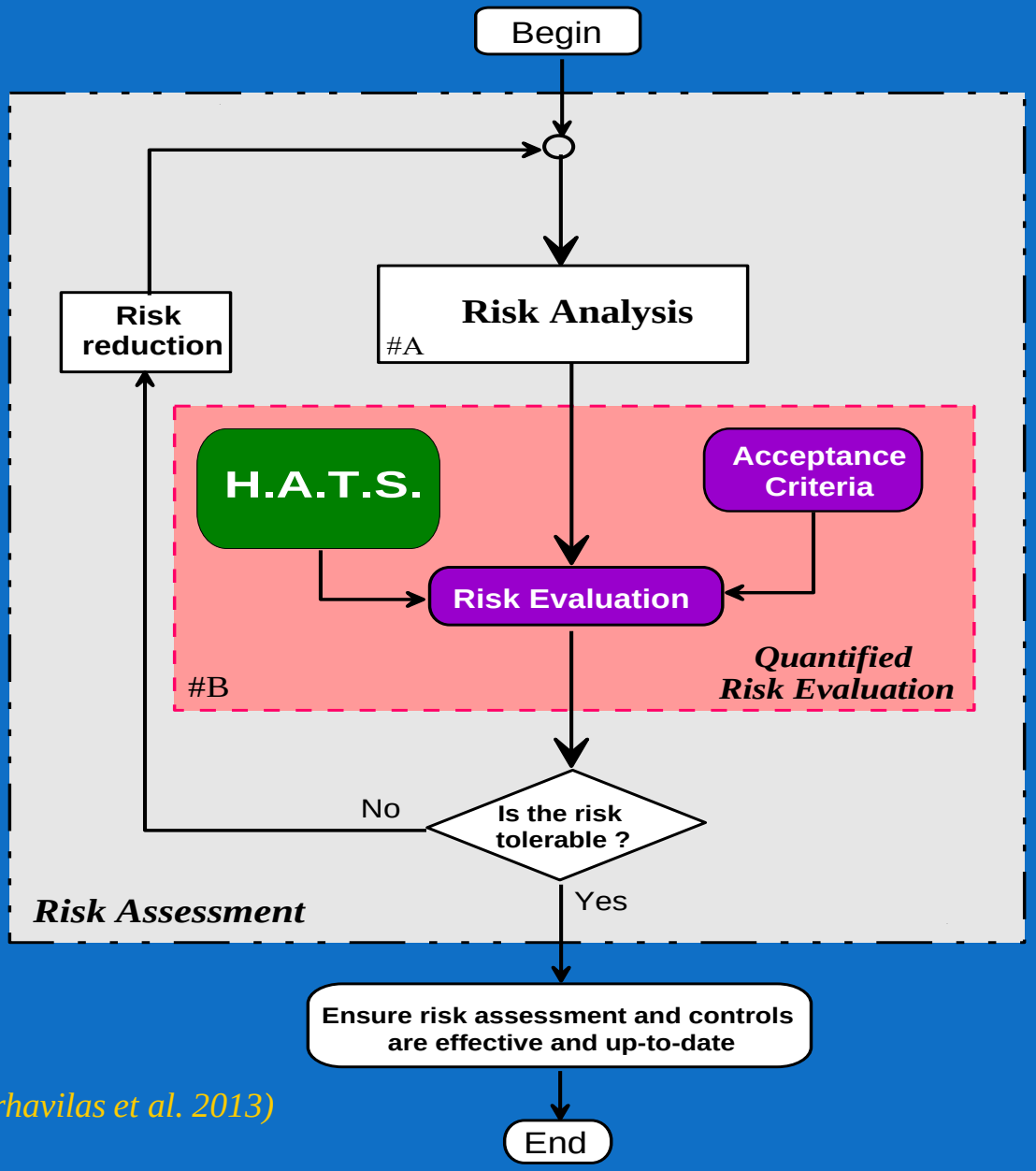
Ανάλυση τάσης

μέθοδοι για ταυτοποίηση της τάσης:

1. **γραμμικό φιλτράρισμα** (smoothing, low-pass filtering)
2. **μέθοδος διαφορών** (differencing)
3. **προσαρμογή** (fitting) μιας συνάρτησης

Ανάλυση χρονοσειρών R(t)

Harmonic Analysis of occupational-accident **Time-Series**

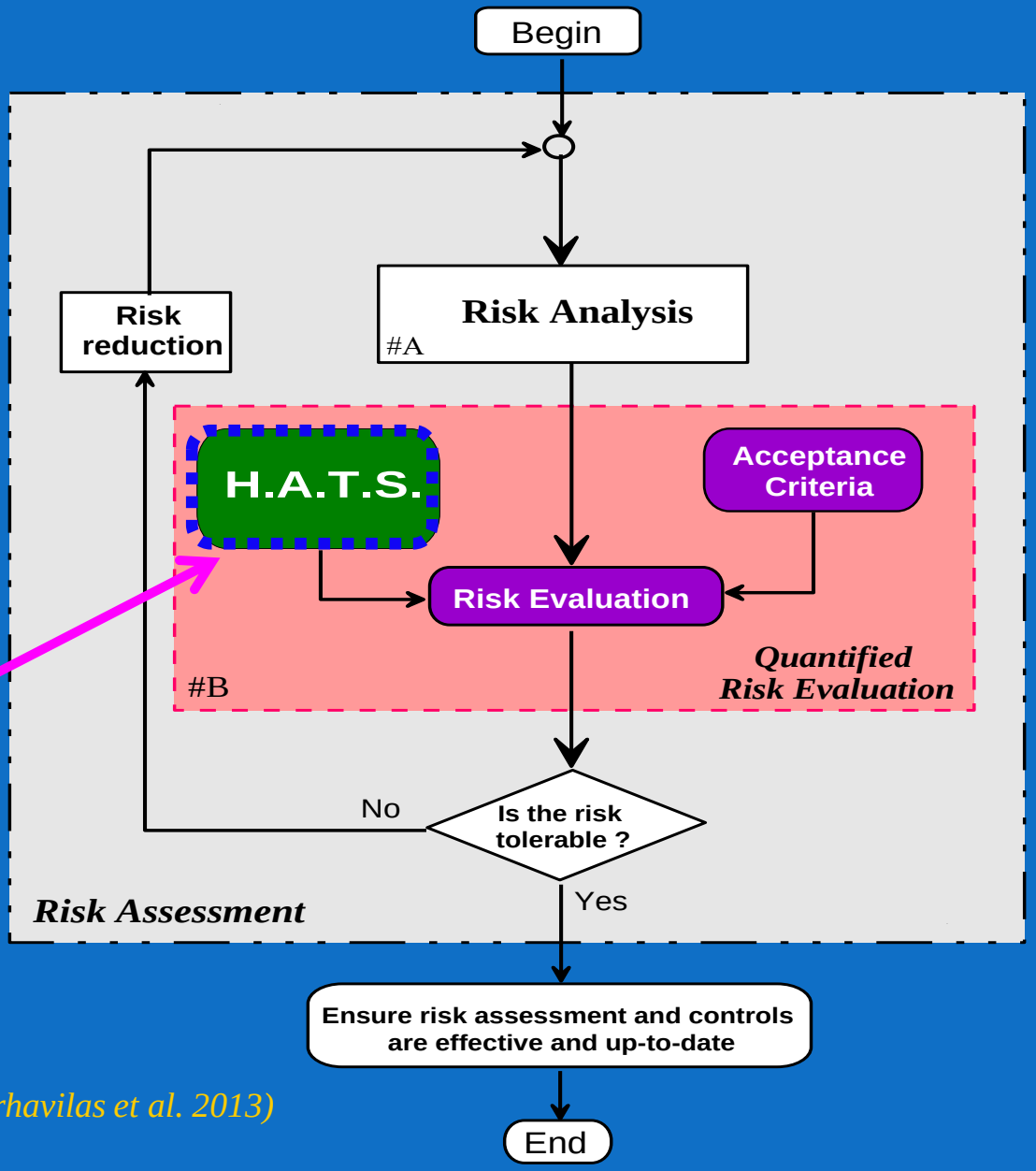


*(**J.RESS**: Marhavilas & Koulouriotis 2012; Marhavilas et al. 2013)*

Ανάλυση χρονοσειρών R(t)

Harmonic Analysis of occupational-accident **Time-Series**

HATS



*(**J.RESS**: Marhavilas & Koulouriotis 2012; Marhavilas et al. 2013)*

TSP: Time-Series Stochastic Processes

Ανάλυση χρονοσειρών
(Time Series)

Πεδίο χρόνου
(t)

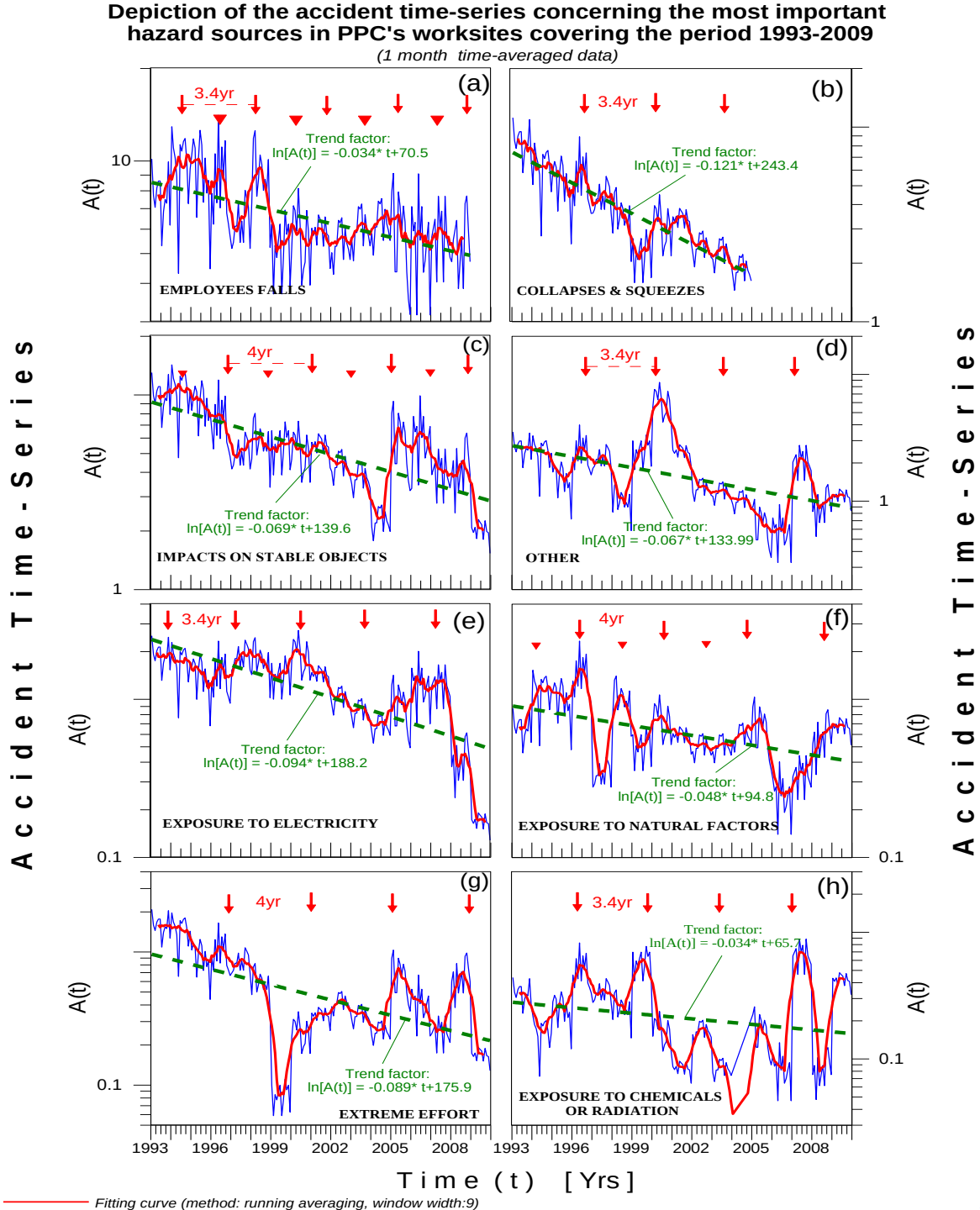
Πεδίο συχνότητας
(f)

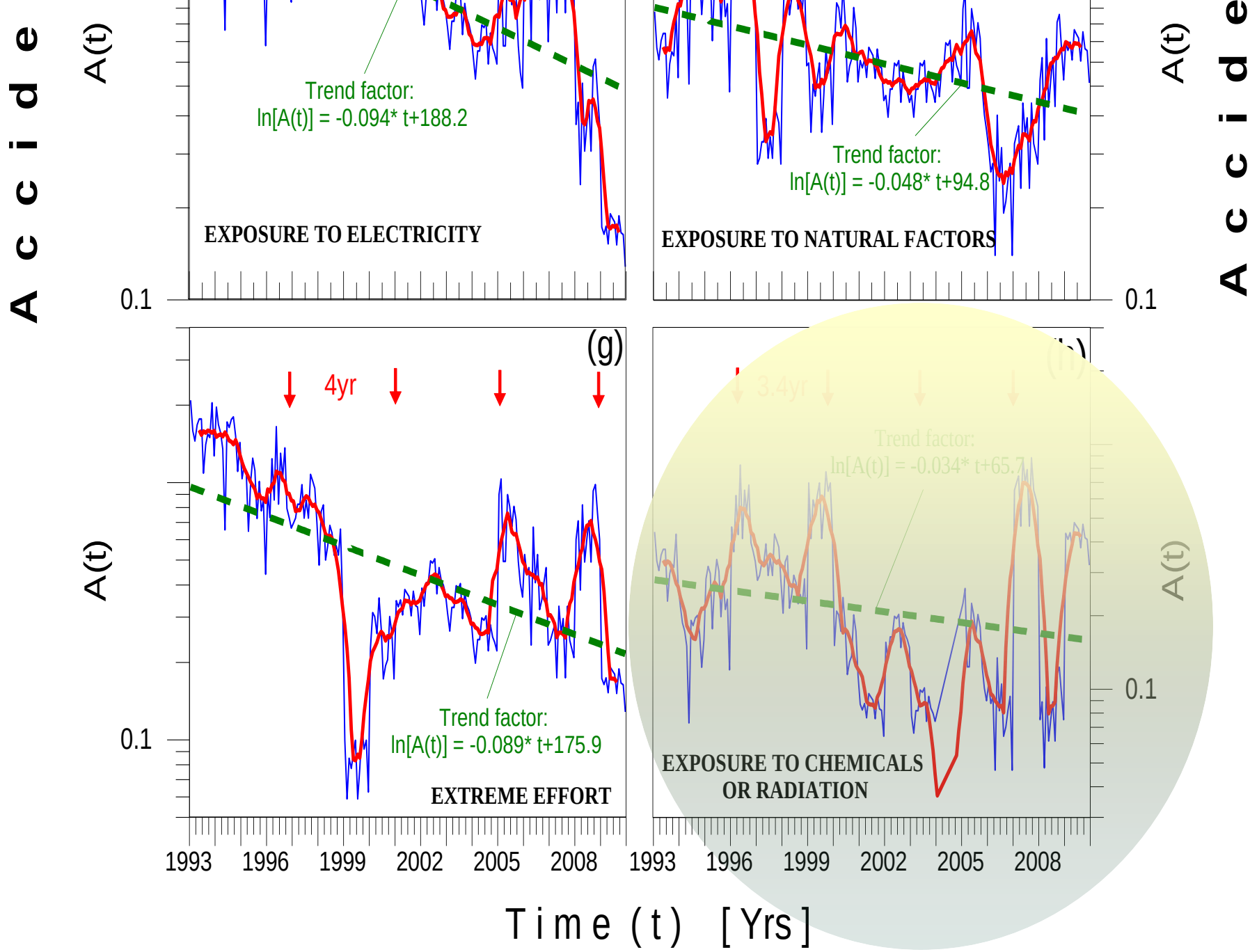
1. Κλίσεις
2. Περιοδικότητες

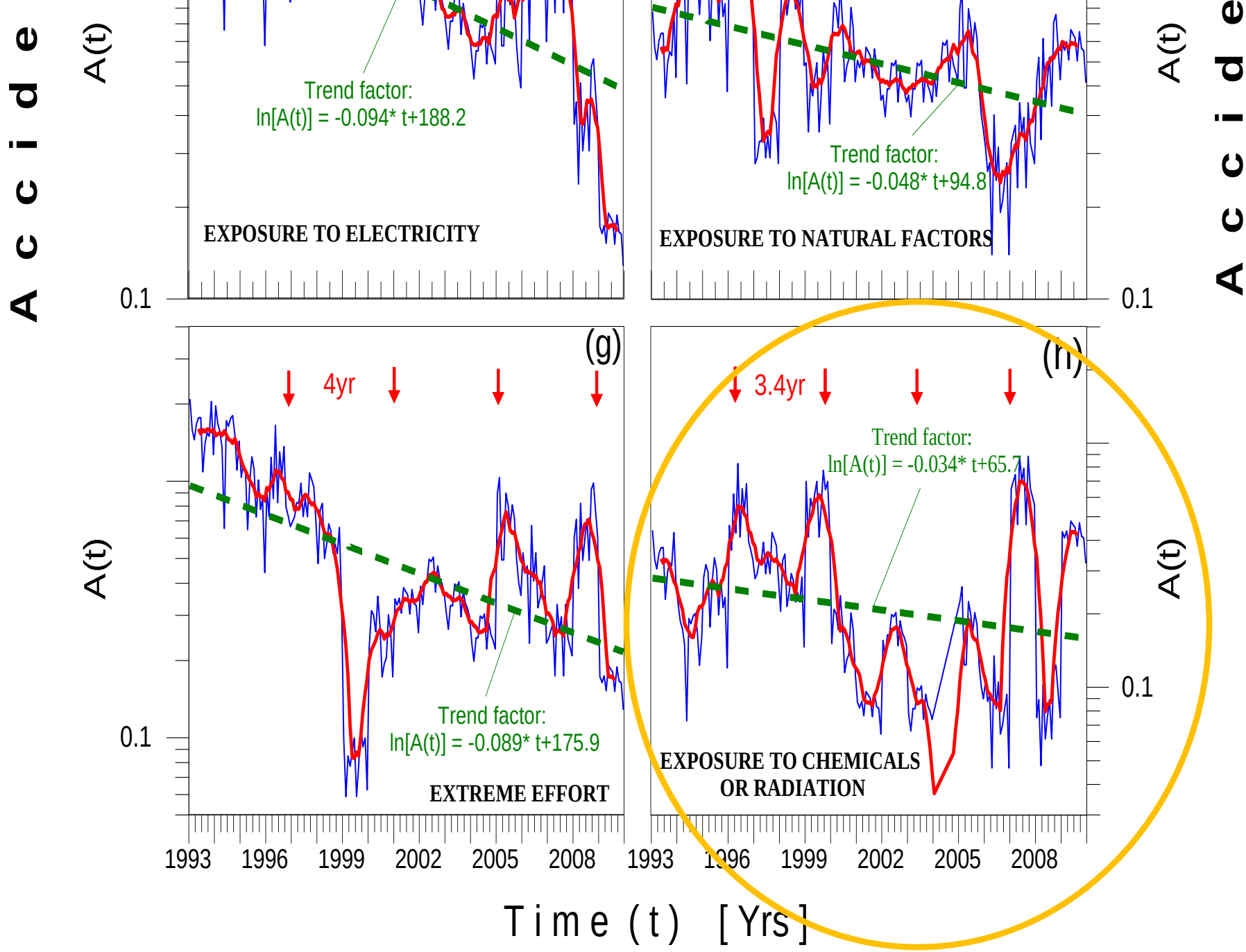
Φάσμα αρμονικών πλατών
(περιοδόγραμμα)
Φάσμα ισχύος (Power spectrum)

Time-profile of the **number of accidents** (or undesirable events) concerning the **most important hazard** sources defined and classified in **PPC** by safety managers for the period

1993-2009




Accidents
A(t)
Trend factor:
ln[A(t)] = -0.094* t+188.2
EXPOSURE TO ELECTRICITY
Trend factor:
ln[A(t)] = -0.048* t+94.8
EXPOSURE TO NATURAL FACTORS
0.1
(g)
4yr
Trend factor:
ln[A(t)] = -0.089* t+175.9
EXTREME EFFORT
3.4yr
Trend factor:
ln[A(t)] = -0.034* t+65.7
EXPOSURE TO CHEMICALS
OR RADIATION
1993
1996
1999
2002
2005
2008
Time (t) [Yrs]
Fitting curve (method: running averaging, window width:9)


A c c i d e
A(t)
Trend factor:
ln[A(t)] = -0.094* t+188.2
EXPOSURE TO ELECTRICITY
Trend factor:
ln[A(t)] = -0.048* t+94.8
EXPOSURE TO NATURAL FACTORS
0.1
(g)
4yr
Trend factor:
ln[A(t)] = -0.089* t+175.9
EXTREME EFFORT
(h)
3.4yr
Trend factor:
ln[A(t)] = -0.034* t+65.7
EXPOSURE TO CHEMICALS
OR RADIATION
1993
1996
1999
2002
2005
2008
Time (t) [Yrs]
Fitting curve (method: running averaging, window width:9)

TSP: Time-Series Stochastic Processes

Ανάλυση χρονοσειρών
(Time Series)

Πεδίο χρόνου
(t)

1. Κλίσεις
2. Περιοδικότητες

Πεδίο συχνότητας
(f)

Φάσμα αρμονικών πλατών
(περιοδόγραμμα)
Φάσμα ισχύος (Power spectrum)

Αρμονική ανάλυση

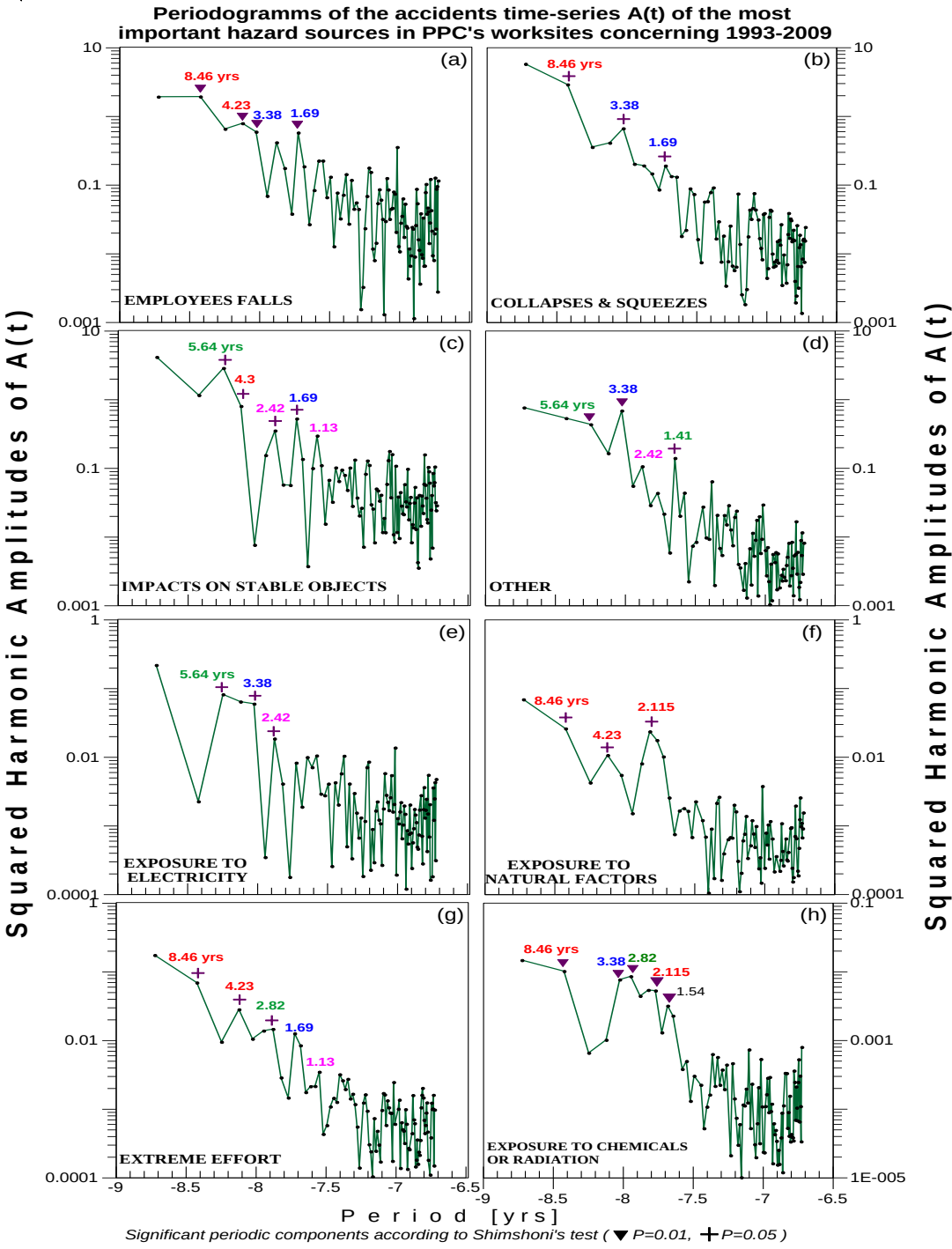
- Υποθέτουμε ότι μια χρονοσειρά Xt, t = 1, 2,…n μπορεί να γραφεί σαν άθροισμα αρμονικών μεταβλητών στη μορφή:

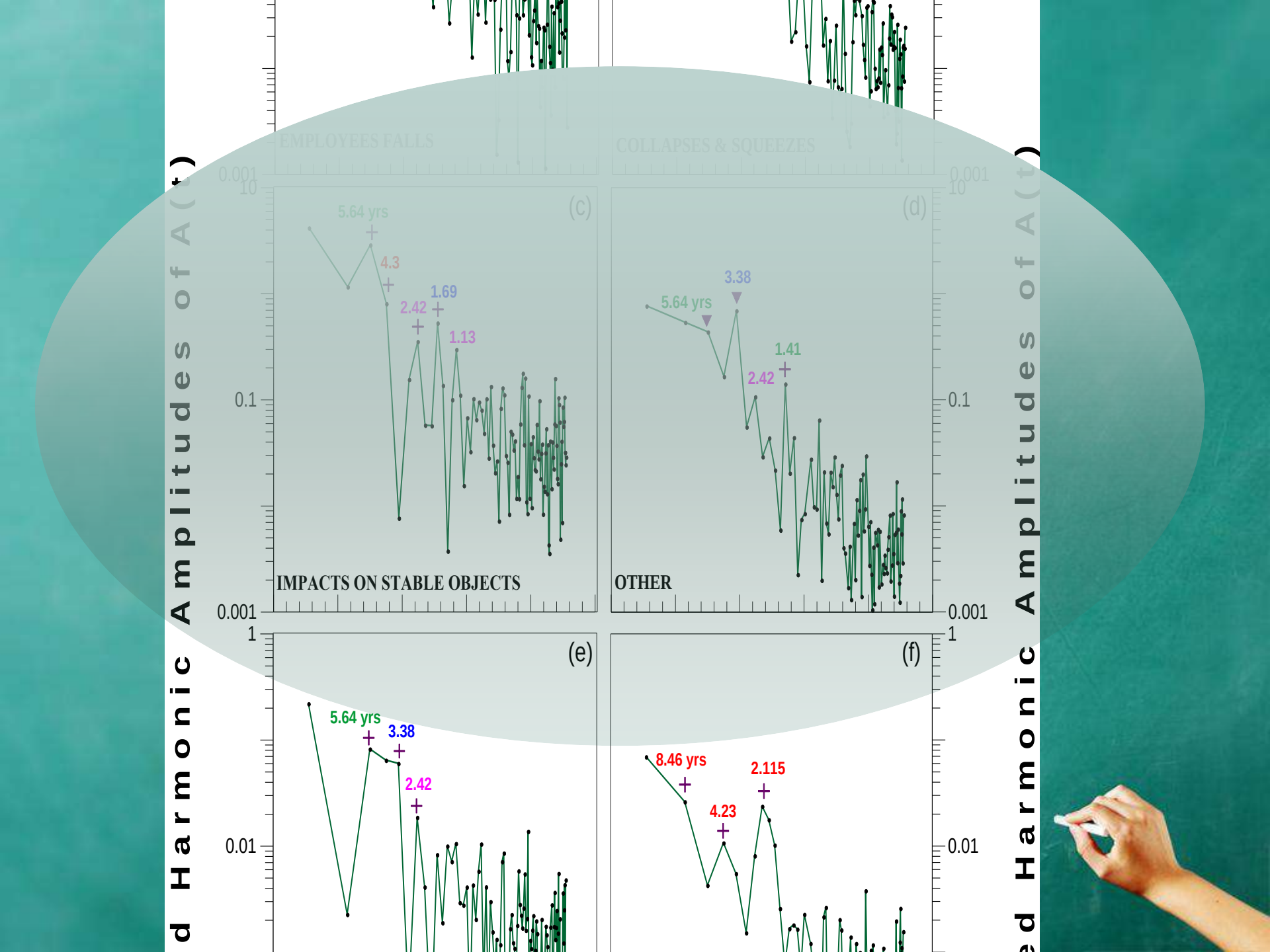
$$x_t = \frac{a_0}{2} + \sum_{k=1}^{m} \left[a_k \cos\left(\frac{2\pi kt}{n}\right) + b_k \sin\left(\frac{2\pi kt}{n}\right) \right]$$

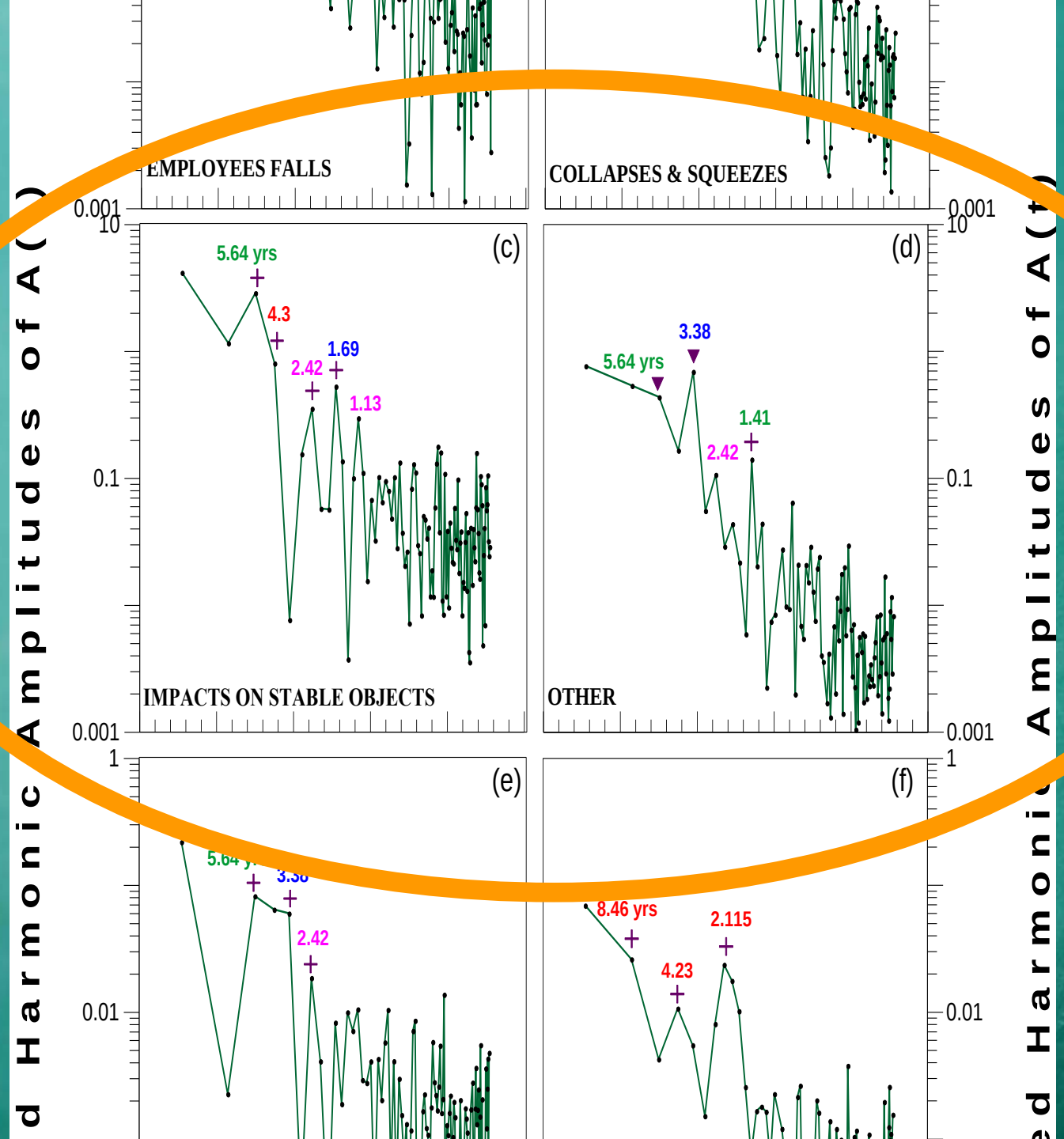
Όπου οι ποσότητες a0, ak, bk είναι τα αρμονικά πλάτη.

- Υπολογίζεται το τετράγωνο των Α.Π. και το άθροισμά τους.
- Γίνεται σύγκριση με τον πίνακα σημαντικότητας του Fisher.

Spectra (or **periodogramms**) produced by applying the **harmonic analysis** on the accident time-series **A(t)** of the most important hazard sources in PPC worksites during **1993-2009**

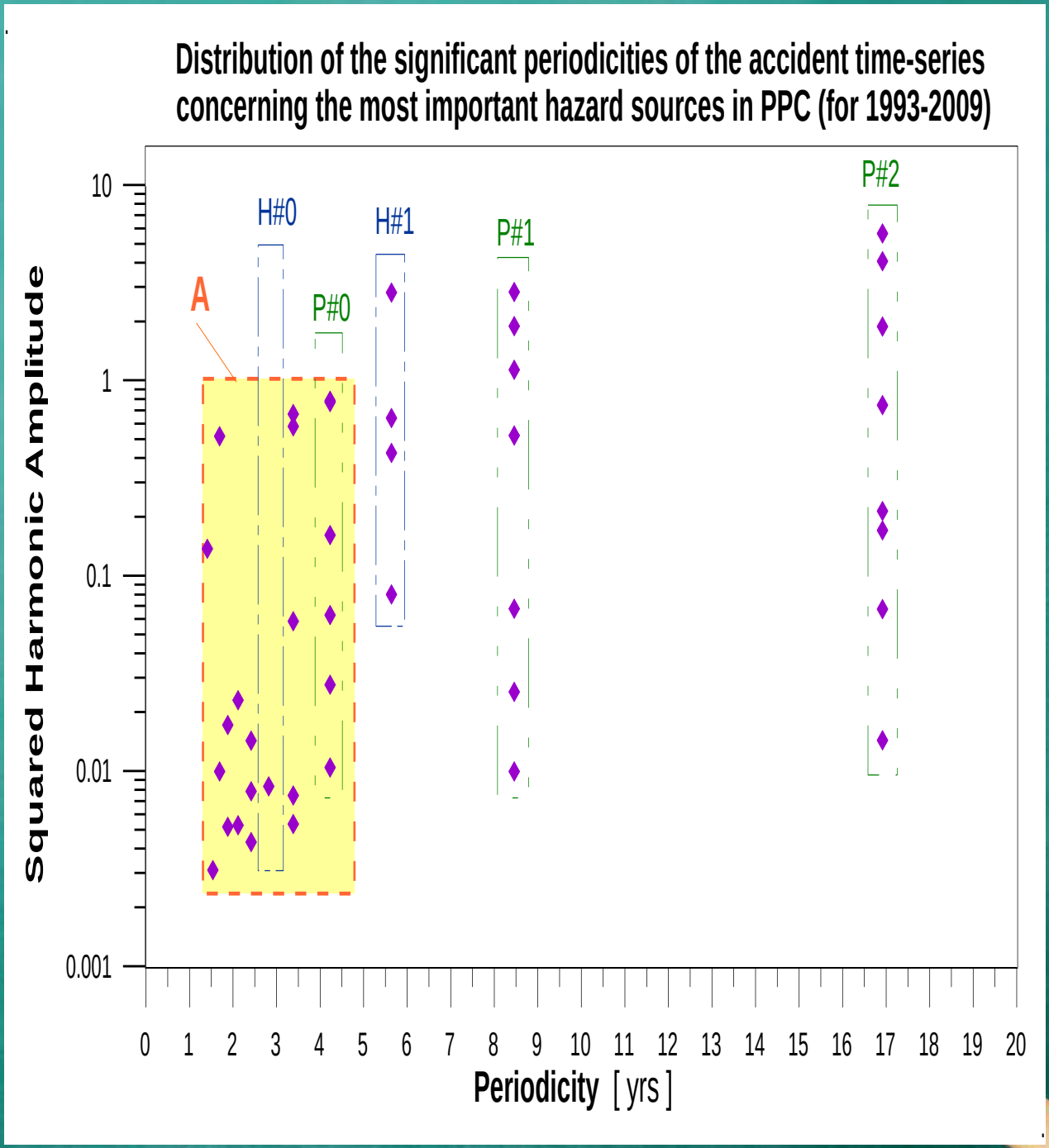



Normalized Harmonic Amplitudes of A(t)
EMPLOYEES FALLS
COLLAPSES & SQUEEZES
(c)
5.64 yrs
4.3
1.69
2.42
1.13
IMPACTS ON STABLE OBJECTS
(d)
3.38
5.64 yrs
1.41
2.42
OTHER
(e)
5.64 yrs
3.38
2.42
(f)
8.46 yrs
2.115
4.23
10
1
0.1
0.01
0.001


EMPLOYEES FALLS
COLLAPSES & SQUEEZES
(c)
5.64 yrs
4.3
1.69
2.42
1.13
IMPACTS ON STABLE OBJECTS
(d)
3.38
5.64 yrs
1.41
2.42
OTHER
(e)
2.42
(f)
8.46 yrs
2.115
4.23
10
1
0.1
0.01
0.001

Spectro-graphical distribution of the significant **periodicities**

P#1, P#2, H#1 : harmonic multiples of the basic periodicities P#0 and H#0



Color-map of periodic components from harmonic analysis in PPC's worksites (1993-2009)

	Hazard Sources	Periodic Components of A(t) *[yrs]*											
		8.46	**5.64**	**4.3**	**4.23**	**3.38**	**2.82**	**2.42**	**2.12**	**1.69**	**1.54**	**1.41**	**1.13**
A	EMPLOYEES FALLS	√			√	√				√			
B	COLLAPSES & SQUEEZES	√				√				√			
C	IMPACTS ON FIXED OBJECTS		√	√				√		√			√
G	EXTREME EFFORT	√			√		√			√			√
F	EXPOSURE TO NATURAL FACTORS	√			√				√				
E	EXPOSURE TO ELECTRICITY		√			√		√					
H	EXPOSURE TO CHEMICALS OR RADIATION	√				√	√		√		√		
D	OTHER		√			√		√				√	

* TSP in PPC (for 1993-2009) are characterized by:

* The **existence** of a **periodic factor** of **~1.5-4 yrs**,

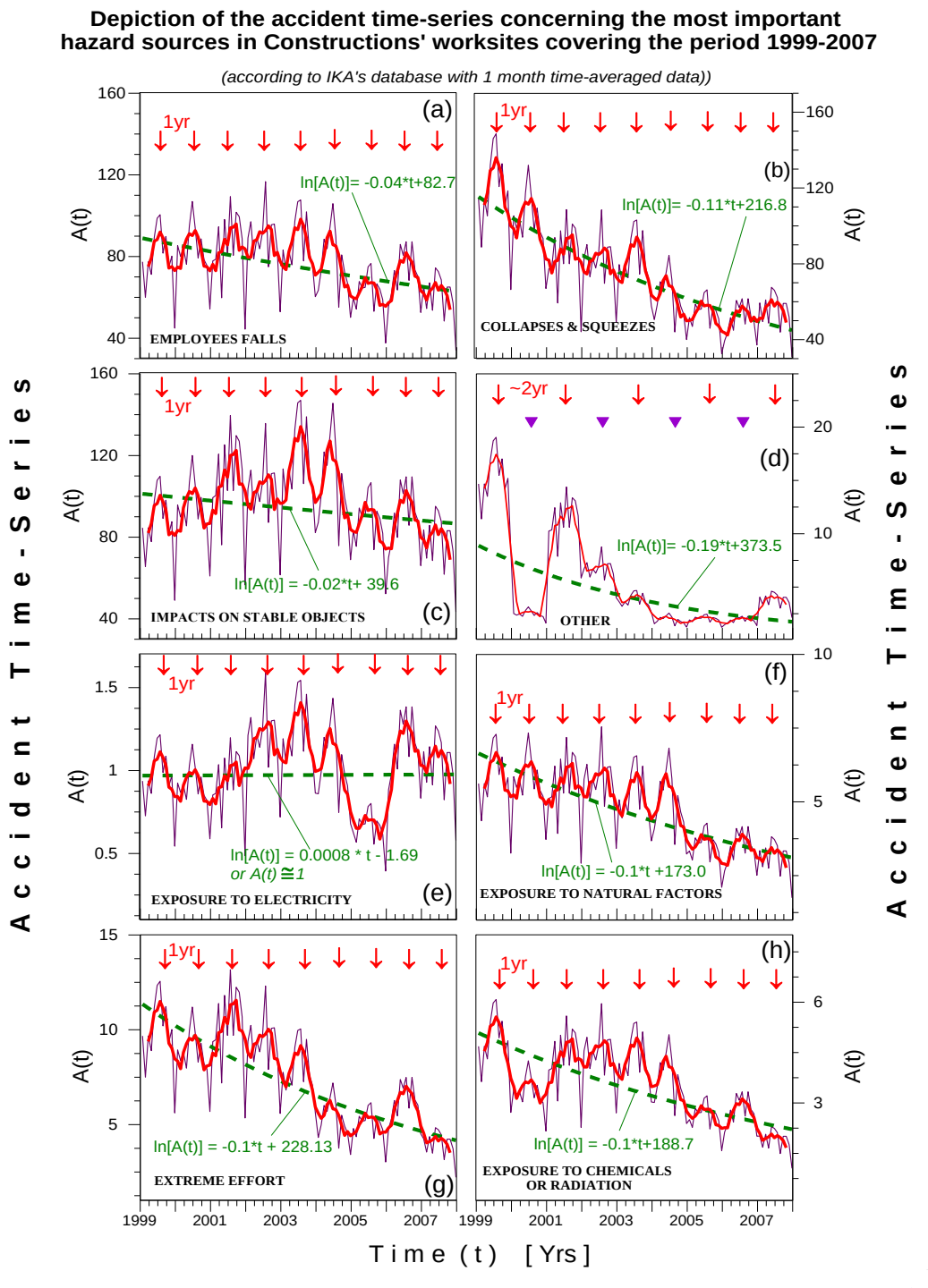
which:

* constitutes a **permanent feature** for the **dynamic behavior** of PPC's system relatively to safety, and

* could be taken **into account** by the company's risk managers in order to achieve more efficient results on risk assessment.

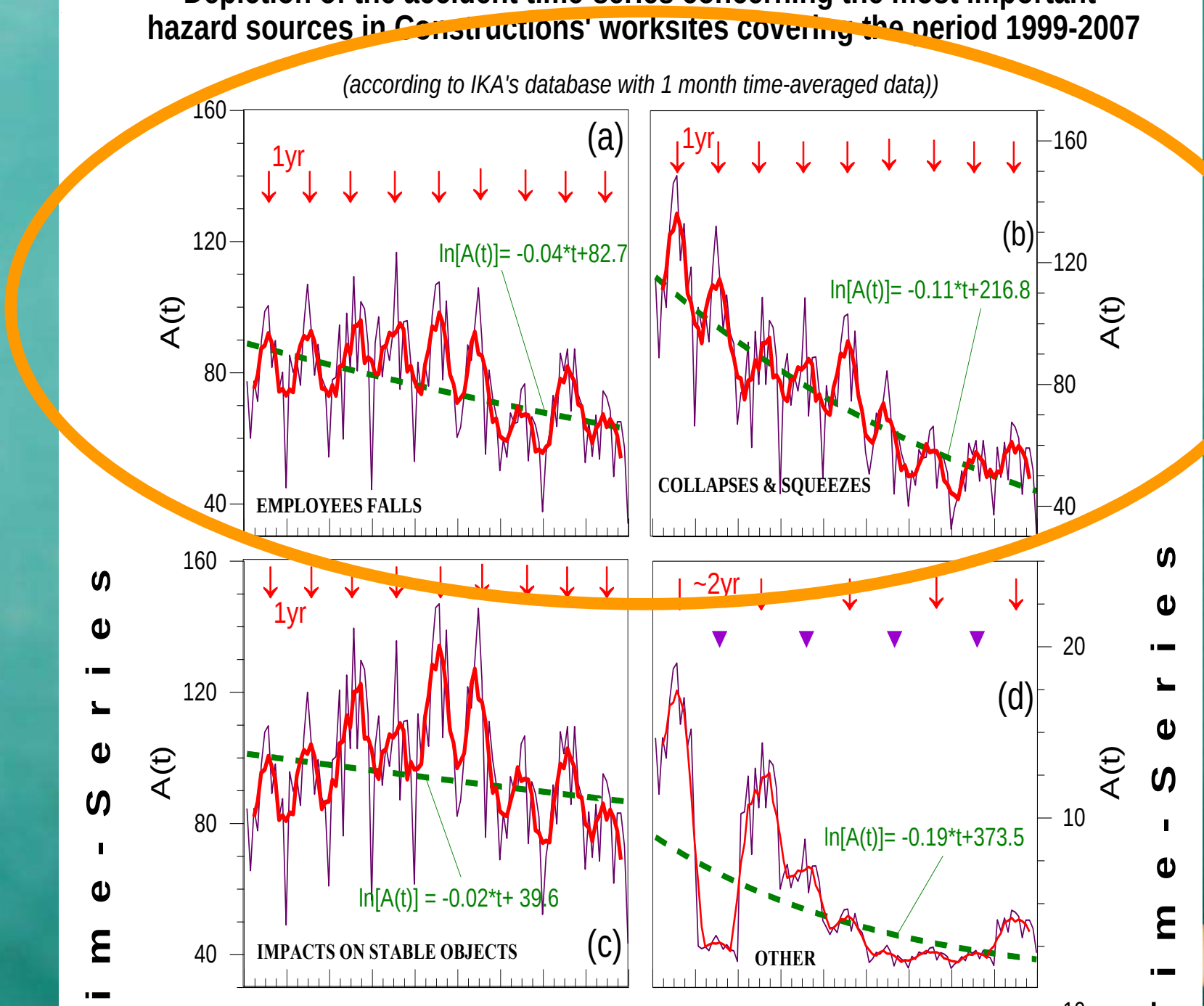
Χρονοσειρές ατυχημάτων στις Κατασκευές

1999-2007



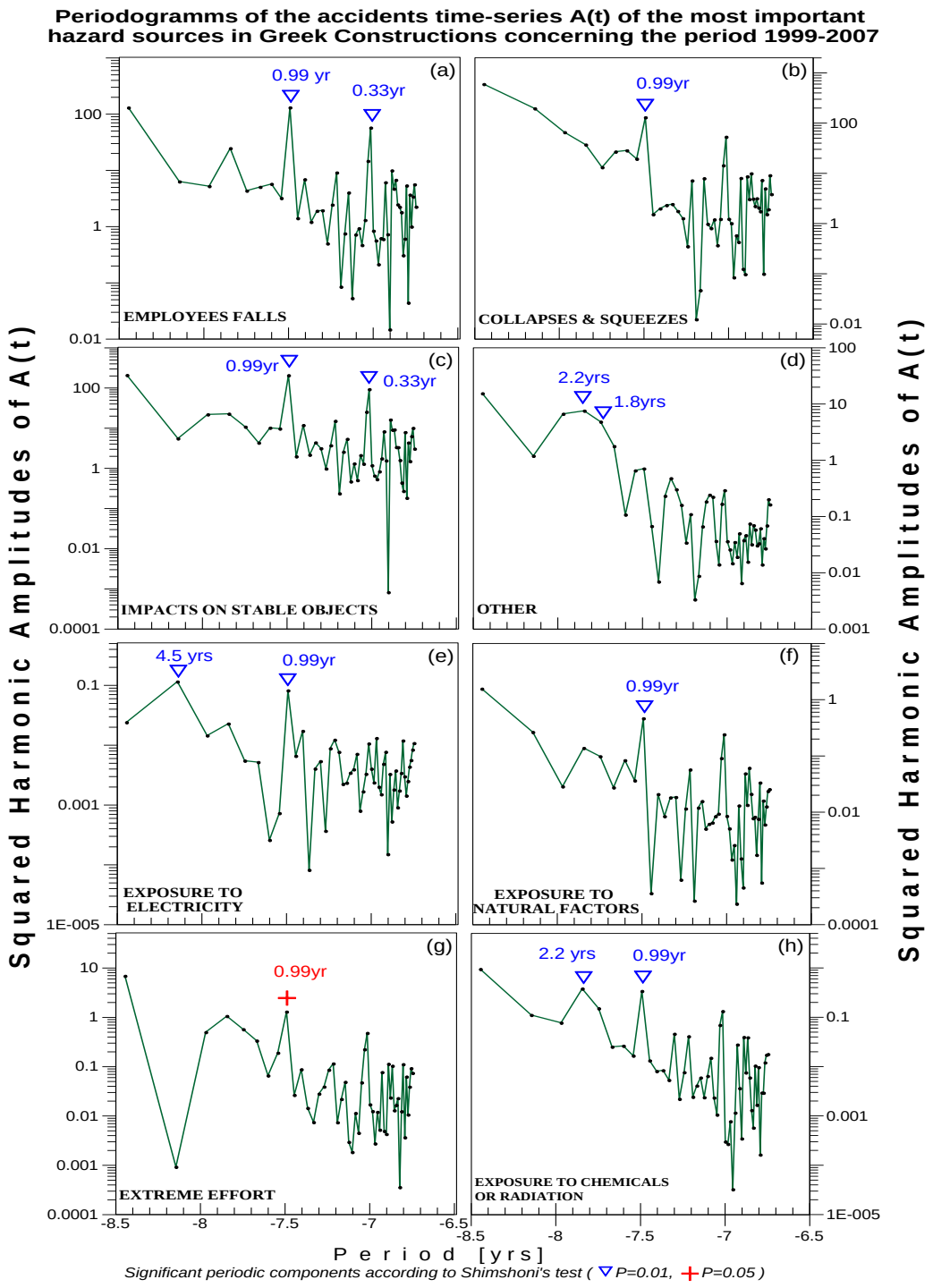
Depiction of the accident time-series concerning the most important hazard sources in Constructions' worksites covering the period 1999-2007

(according to IKA's database with 1 month time-averaged data))

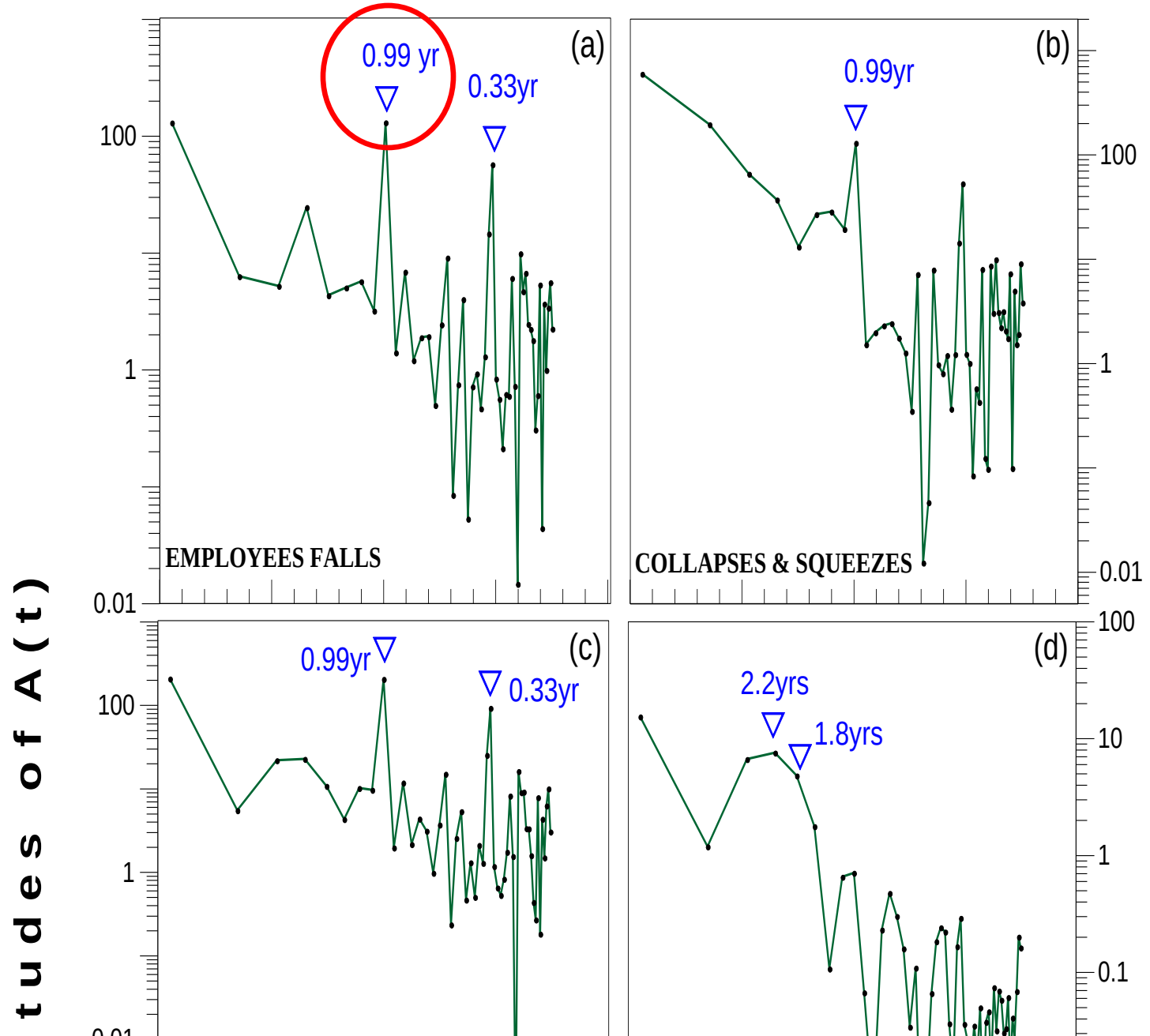


Φάσματα ατυχημάτων στις Κατασκευές

(1999-2007)



Periodogramms of the accidents time-series A(t) of the most important hazard sources in Greek Constructions concerning the period 1999-2007

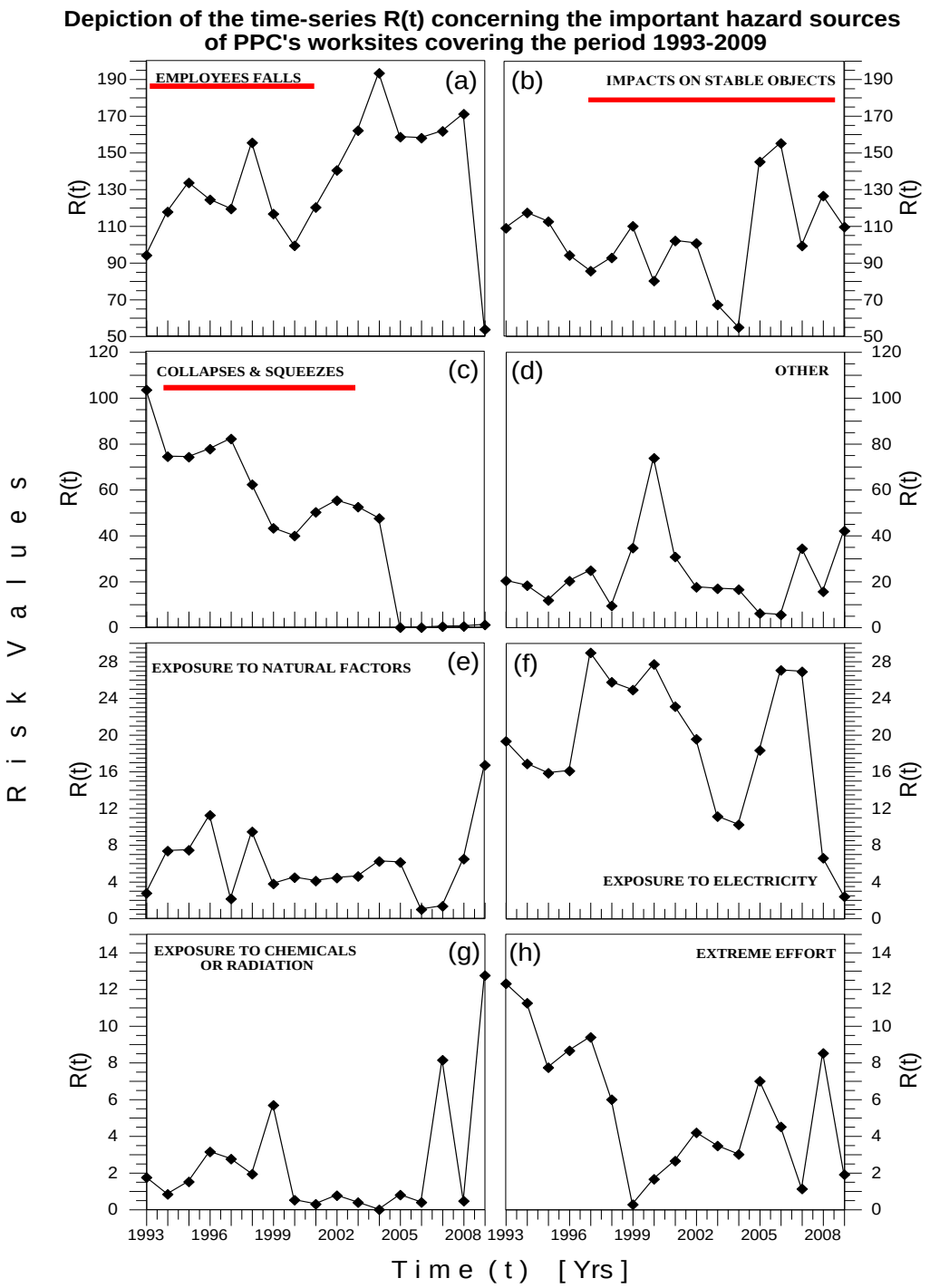


Κατασκευές :

(i) Presence of a long-term **trend factor** with a decreasing or a constant tension

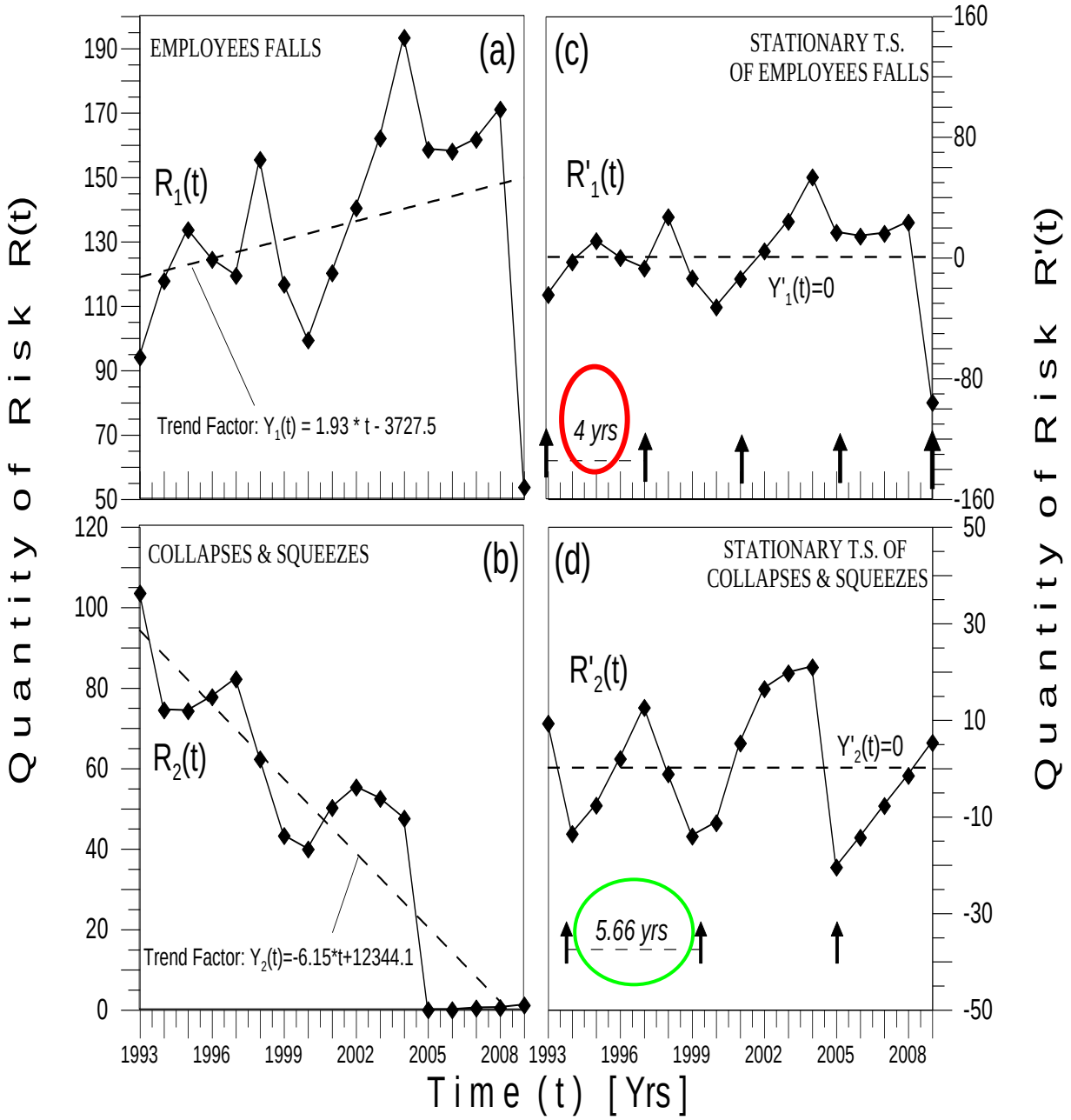
(ii) Presence of a **periodical factor** at a level of **~1.0 yr** (statistically significant)

R(t) calculated in PPC's worksites and concerning the period 1993-2009



Στάσιμες χρονοσειρές

Depiction of the initial-T.S. and the extracted stationary-T.S. for the most important hazard sources in PPC concerning 1993-2009

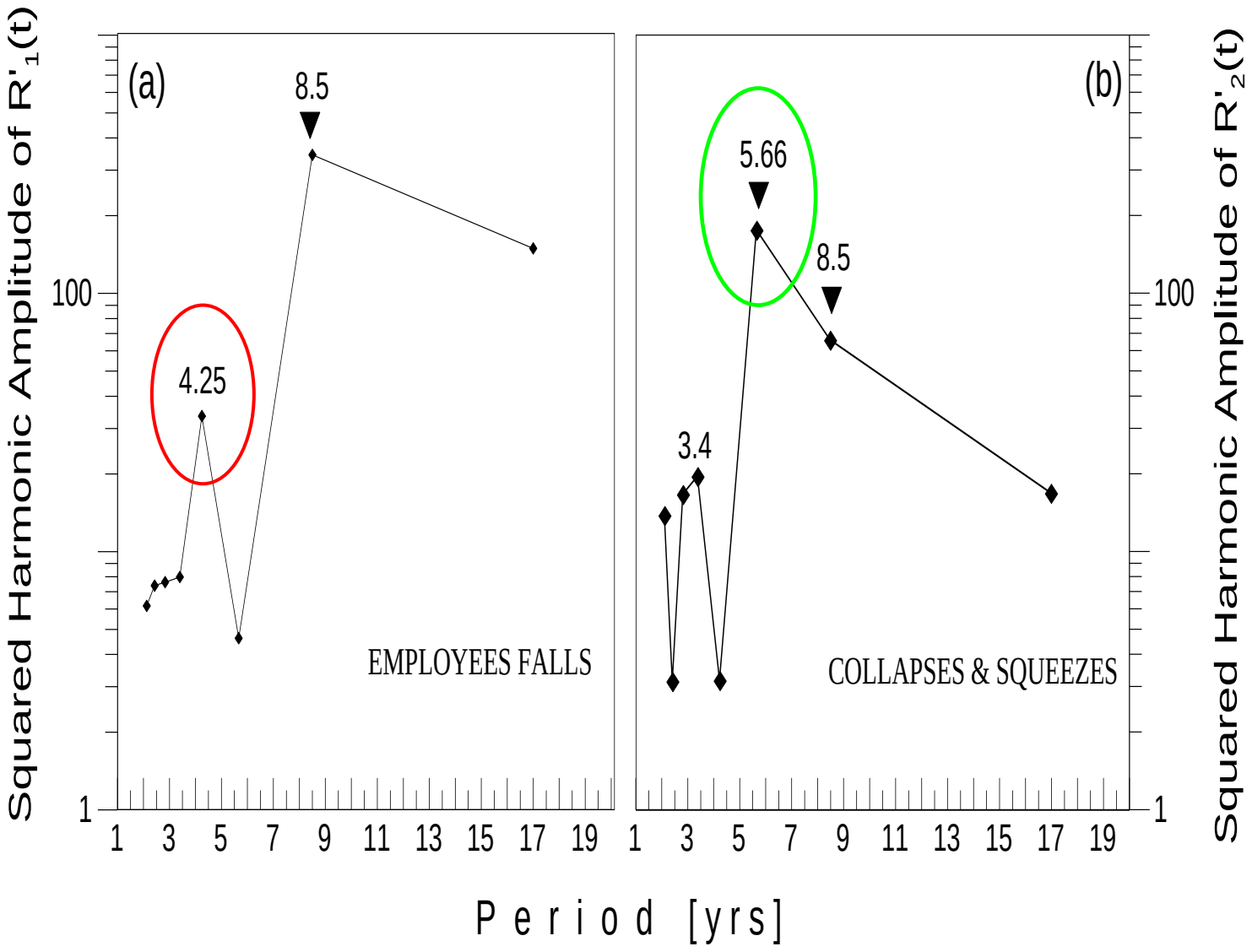


Spectra

of the stationary R'(t)

(1993-2009)

Periodogramms of the stationary-T.S. R'(t) of the most important hazard sources in PPC concerning 1993-2009



▼ *Significant periodic components according to Fisher's test*

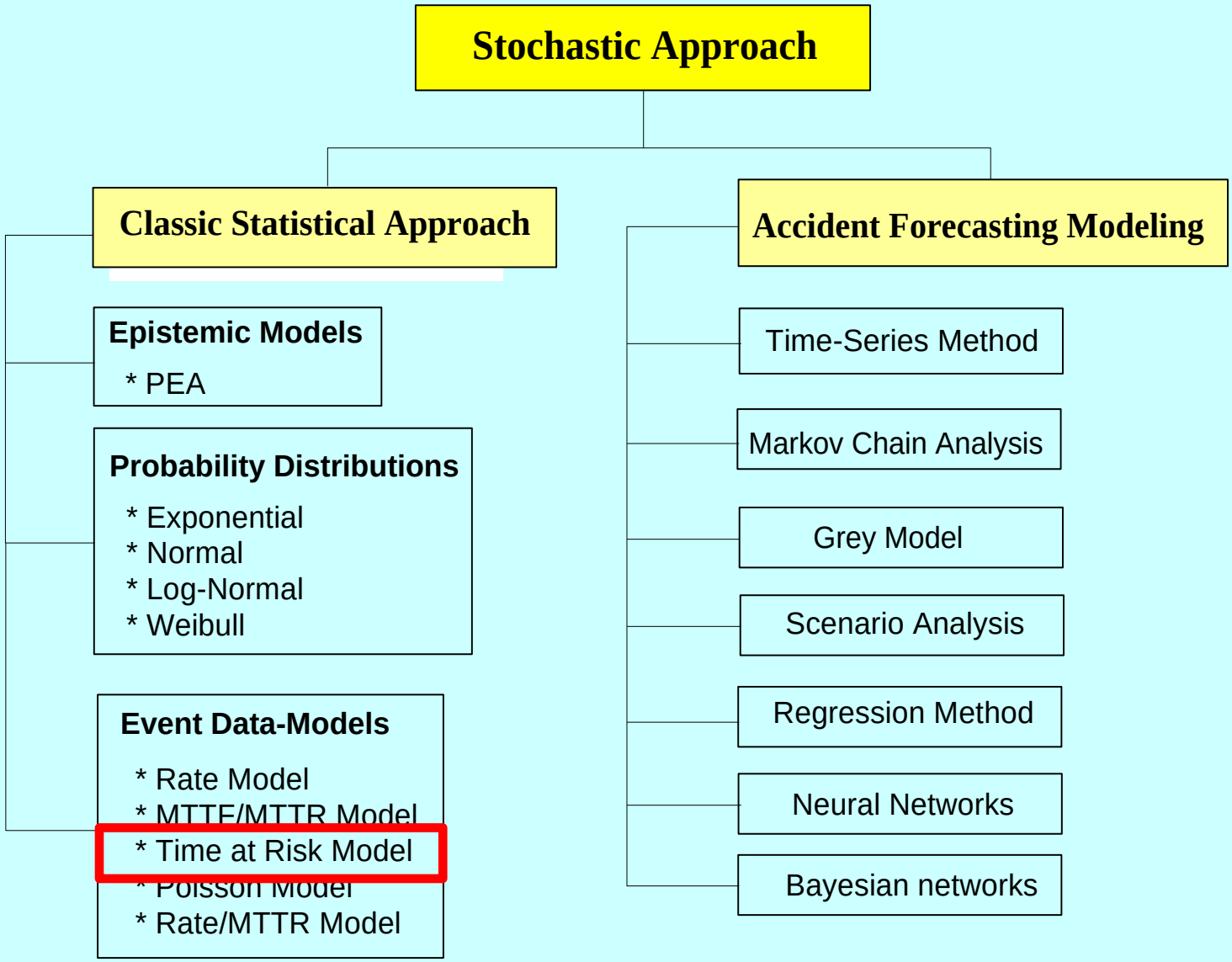
The results of the **harmonic analysis** applied on R(t) of the most important hazard sources (PPC's worksites, for **1993-2009**)

Hazard Sources	Periodic Components *[yrs]*				
	8.5	5.66	4.25	3.4	2.83
EMPLOYEES FALLS	√		√	√	
COLLAPSES & SQUEEZES	√	√		√	√
IMPACTS ON STABLE OBJECTS		√		√	
EXTREME EFFORT	√				√
EXPOSURE TO NATURAL FACTORS		√			√
EXPOSURE TO ELECTRICITY	√	√		√	√
EXPOSURE TO CHEMICALS OR RADIATION	√	√		√	√
OTHER	√		√	√	

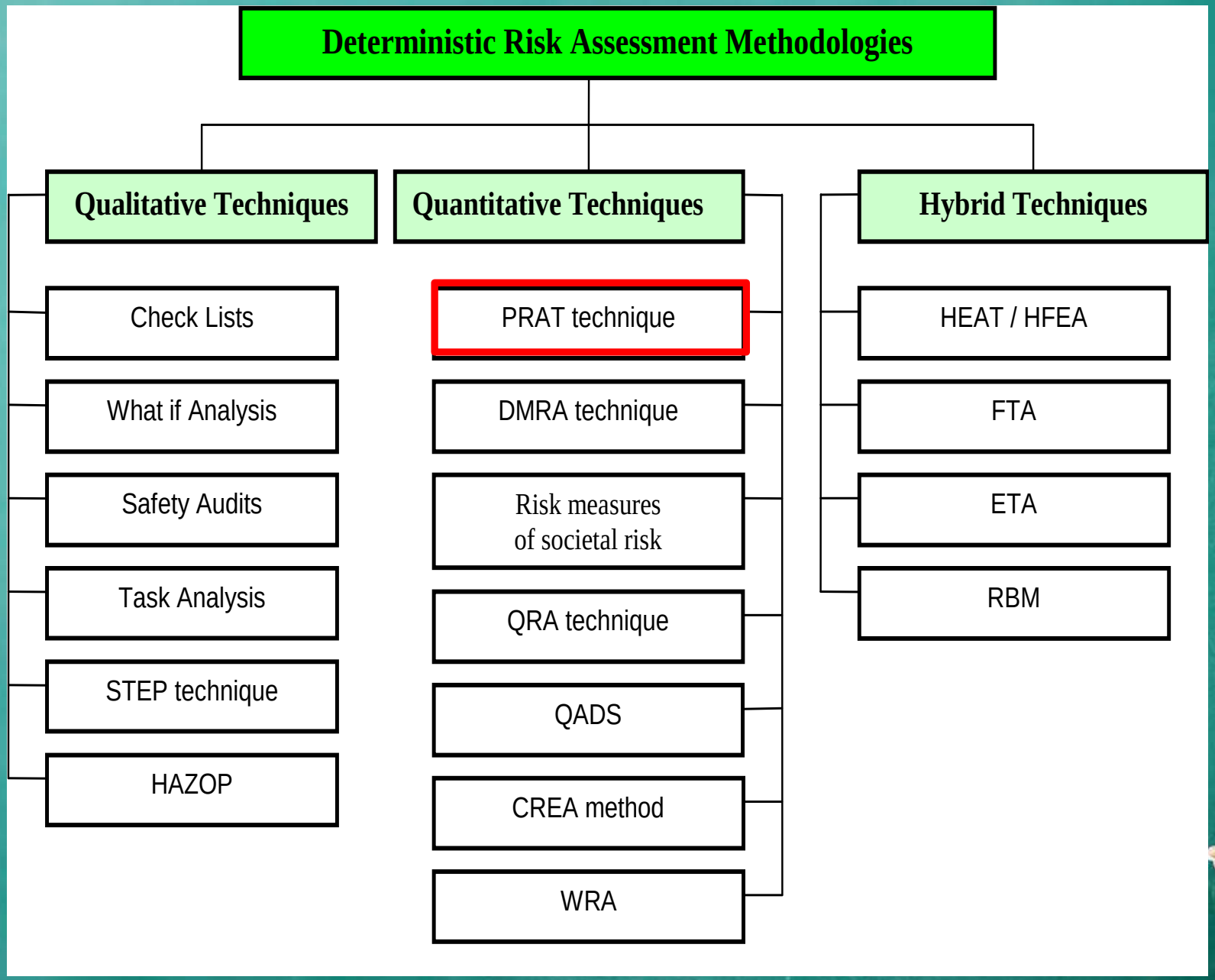
~3.5-5.5 yrs

A permanent characteristic for the dynamic behavior of PPC's system

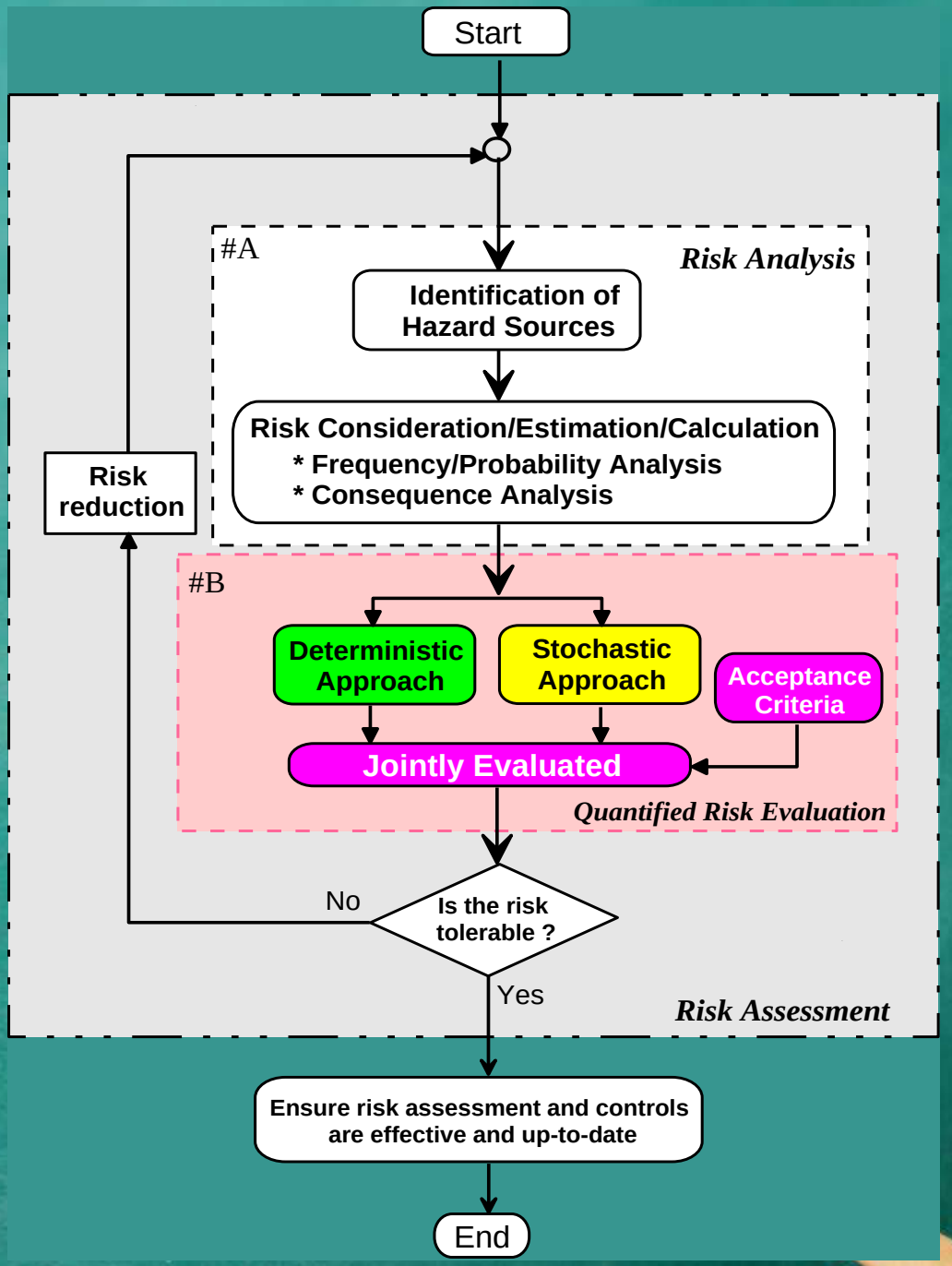
Πιθανοκρατικές Τεχνικές



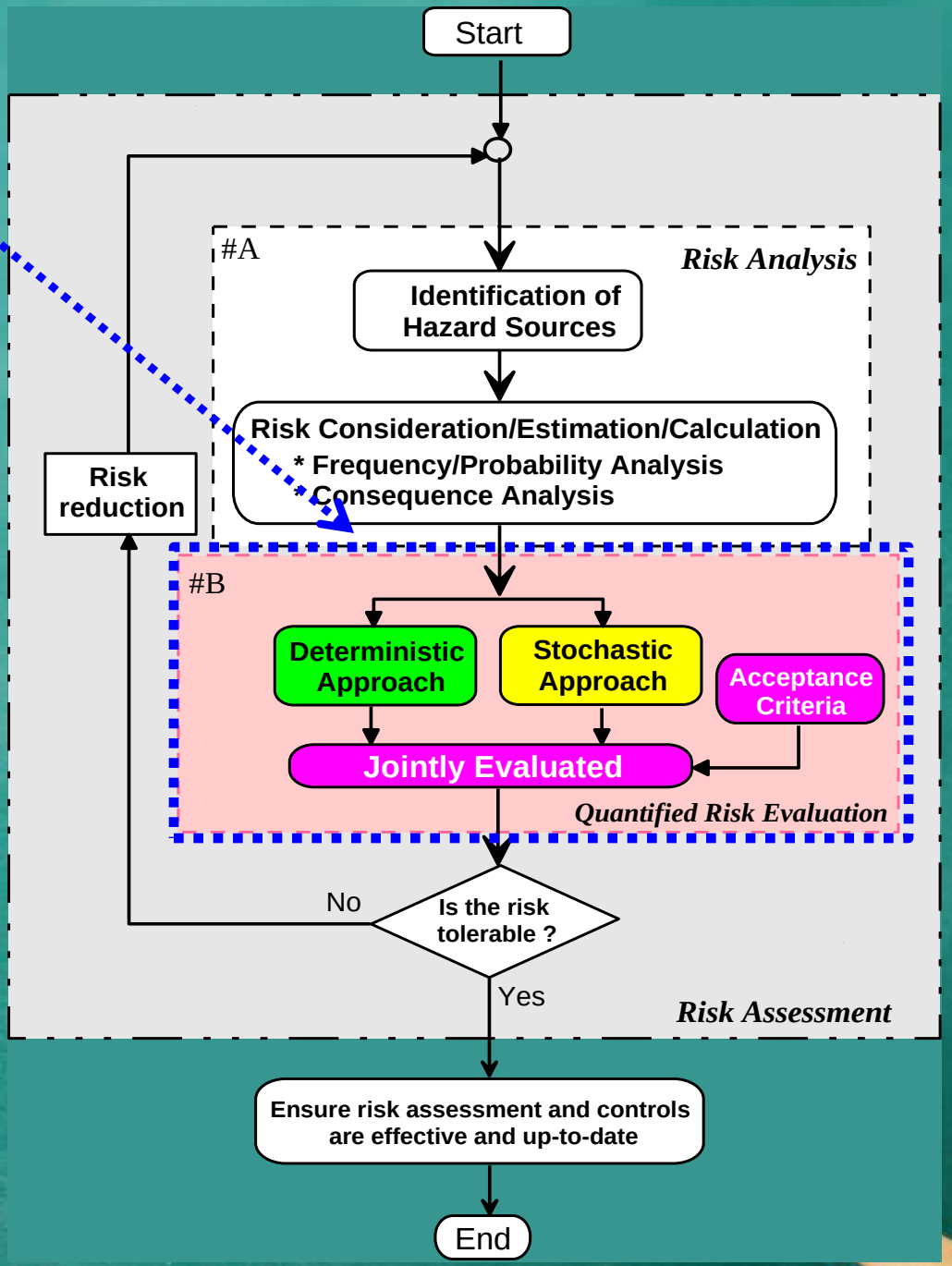
Αιτιοκρατικές Τεχνικές



The flowchart of quantified risk-evaluation, implemented by the combination and the jointly evaluation of a **Stochastic** and a **Deterministic** process.



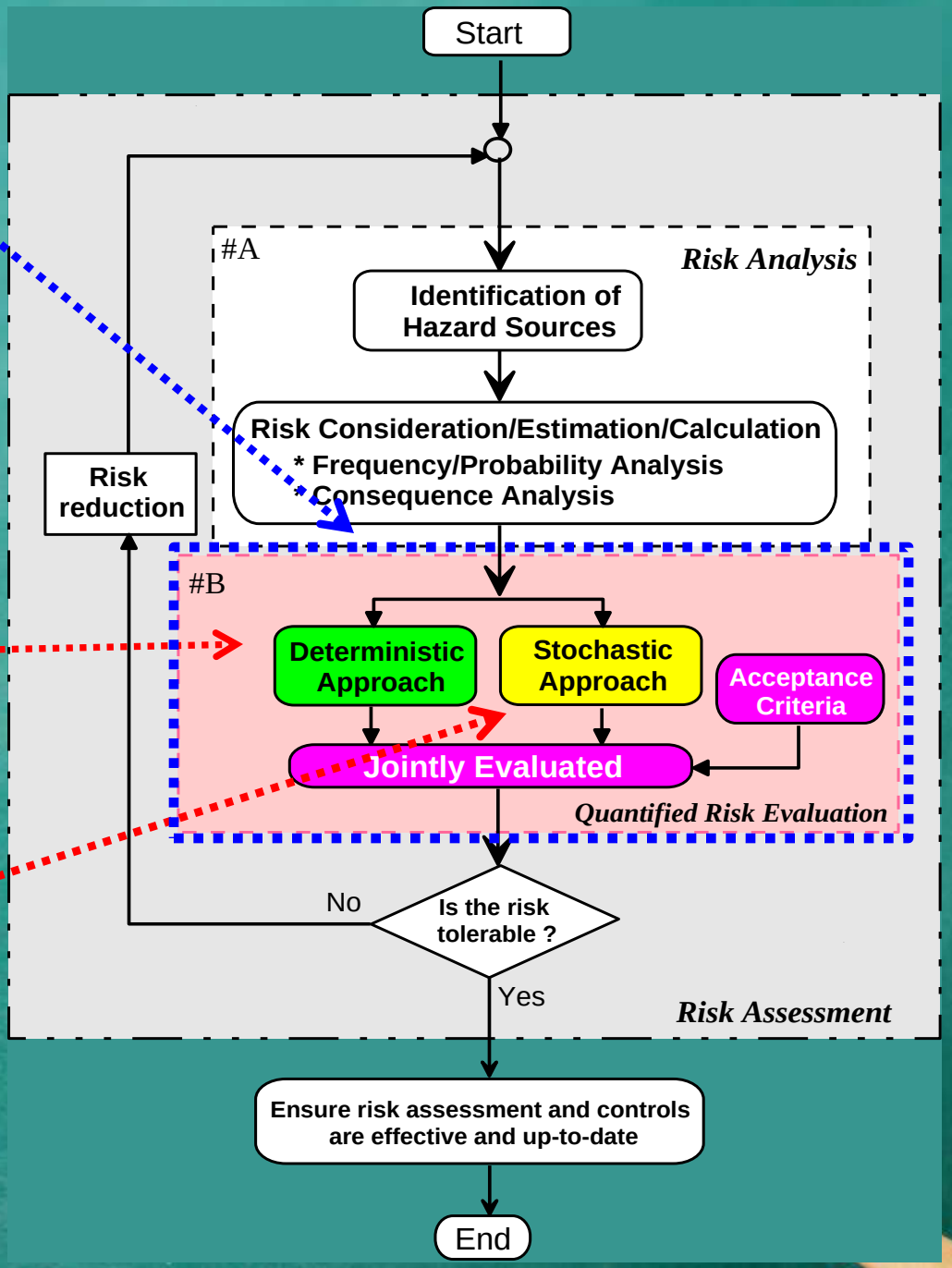
The flowchart of **STODET** quantified risk-evaluation, implemented by the combination and the jointly evaluation of a **Stochastic** and a **Deterministic** process.



The flowchart of **STODET** quantified risk-evaluation, implemented by the combination and the jointly evaluation of a **Stochastic** and a **Deterministic** process.

PRAT

Time at Risk Failure Model



Αστοχία (Failure) και Αξιοπιστία (Reliability)

Basic Reliability Equations

* $R=e^{-\lambda t}$
* $R+Q=1$
* $Q=1-R= 1- e^{-\lambda t}$

Approximation

When $\lambda T<0.001$ then $Q \cong \lambda T$

Where:

R= Reliability or probability of success

Q= Unreliability or probability of failure

λ= component failure rate =1/MTBF (mean time between failures)

T= time interval (mission time or exposure time)

A stochastic model: "Time at Risk Failure Model"

Probability of failure:

$$Q(t) = 1 - e^{-\lambda T}$$

λ : failure rate

T : time of exposure

A stochastic model: “Time at Risk Failure Model”

“**mean time**” plays a very important role in connection with the reliability and the probability of failure of OHSS

One **significant** “**mean time**” is the “***mean time between failures***” (**MTBF**) :

$$\lambda = 1 / \mathrm{MTBF}$$

Risk-value **R** and its maximum value R_{max} , which have been calculated by applying the PRAT technique on the most important hazard sources defined in **PPC's** OHSS [**1993-2009**] **Probability of failure Q** of PPC's OHSS system by applying the "**Time at Risk Failure**" stochastic model, and using the total accidents and the corresponding **MTBF**

Hazard Sources	**Risk Value (R)**																	Total Accidents	**Max value of Risk** (R_{max})	**MTBF** [hr]	**Q** (%) *[T=1w. week]*	**Q** (%) *[T=1w. month]*	**Q** (%) *[T=1w. yr]*
(A)	**(B)**																	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1993-2009**	**1993-2009**	**1993-2009**			
EMPLOYEES FALLS	94.2	117.8	133.7	124.5	119.5	155.5	116.7	99.4	120.3	140.5	162.1	193.3	158.6	158.0	161.7	171.1	53.7	1303	193.3	114.3	65.0%	99.0%	100.0%
COLLAPSES & SQUEEZES	103.5	74.5	74.3	77.8	82.2	62.3	43.3	39.9	50.3	55.4	52.5	47.6	0.0	0.0	0.4	0.5	1.2	586	103.5	254.1	37.6%	87.5%	100.0%
IMPACTS ON STABLE OBJECTS	109.0	117.3	112.5	94.2	85.6	92.8	110.0	80.2	102.1	100.7	67.2	54.9	145.1	155.1	99.3	126.5	109.6	1159	155.1	128.5	60.7%	98.4%	100.0%
EXTREME EFFORT	12.3	11.3	7.7	8.7	9.4	6.0	0.3	1.7	2.7	4.2	3.5	3.0	7.0	4.5	1.1	8.5	1.9	123	12.3	1210.7	9.4%	35.3%	99.1%
EXPOSURE TO NATURAL FACTORS	2.8	7.4	7.5	11.3	2.2	9.5	3.8	4.5	4.1	4.4	4.6	6.2	6.1	1.0	1.4	6.5	16.7	138	16.7	1079.1	10.5%	38.7%	99.5%
EXPOSURE TO ELECTRICITY	19.3	16.9	15.9	16.1	29.0	25.8	24.9	27.7	23.1	19.6	11.1	10.2	18.3	27.1	26.9	6.6	2.4	256	29.0	581.7	18.6%	59.7%	100.0%
EXPOSURE TO CHEMICALS OR RADIATION	1.8	0.8	1.5	3.2	2.8	1.9	5.7	0.5	0.3	0.8	0.4	0.0	0.8	0.4	8.2	0.5	12.8	52	12.8	2863.8	4.1%	16.8%	86.6%
OTHER	20.4	18.3	11.9	20.2	24.8	9.5	34.7	73.8	30.8	17.6	16.9	16.5	6.1	5.6	34.4	15.6	42.1	384	73.8	387.8	26.6%	74.4%	100.0%

PRAT

R for PPC's OHSS system (1993-2009)

Sources requiring medium-term actions (R≅200)

* Most important hazard source in PPC : "*EMPLOYEES FALLS*"
* maximum **R=193.3** (i.e. very close to 200)

So, required actions must be done earlier than 1 year in order to degrade the likelihood of arising fatal accidents.

Sources requiring long-term actions (100<R<200)

Additional significant hazard sources: a) "*IMPACTS ON STABLE OBJECTS*" (R=155.1>>100), b) "*COLLAPSES & SQUEEZES*" (R=103.5>100), which present a risk value greater than 100 and long-term actions are essential for the elimination of their potential of danger.

Sources requiring surveillance (R<100)

Other hazard sources: a) "*EXPOSURE TO ELECTRICITY*" (R=29<100), b) "*EXPOSURE TO CHEMICALS OR RADIATION*" (R=12.8<100), which present a risk value lower than 100, and required actions are not necessary but the **events' surveillance** instead.

Risk-value **R** and its maximum value R_{max} , which have been calculated by applying the PRAT technique on the most important hazard sources defined in **PPC's** OHSS [**1993-2009**] **Probability of failure Q** of PPC's OHSS system by applying the "**Time at Risk Failure**" stochastic model, and using the total accidents and the corresponding **MTBF**

Hazard Sources	**Risk Value (R)**																	Total Accidents	**Max value of Risk** (R_{max})	**MTBF** [hr]	**Q** (%) *[T=1w. week]*	**Q** (%) *[T=1w. month]*	**Q** (%) *[T=1w. yr]*
(A)	**(B)**																	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1993-2009**	**1993-2009**	**1993-2009**			
EMPLOYEES FALLS	94.2	117.8	133.7	124.5	119.5	155.5	116.7	99.4	120.3	140.5	162.1	193.3	158.6	158.0	161.7	171.1	53.7	1303	193.3	114.3	65.0%	99.0%	100.0%
COLLAPSES & SQUEEZES	103.5	74.5	74.3	77.8	82.2	62.3	43.3	39.9	50.3	55.4	52.5	47.6	0.0	0.0	0.4	0.5	1.2	586	103.5	254.1	37.6%	87.5%	100.0%
IMPACTS ON STABLE OBJECTS	109.0	117.3	112.5	94.2	85.6	92.8	110.0	80.2	102.1	100.7	67.2	54.9	145.1	155.1	99.3	126.5	109.6	1159	155.1	128.5	60.7%	98.4%	100.0%
EXTREME EFFORT	12.3	11.3	7.7	8.7	9.4	6.0	0.3	1.7	2.7	4.2	3.5	3.0	7.0	4.5	1.1	8.5	1.9	123	12.3	1210.7	9.4%	35.3%	99.1%
EXPOSURE TO NATURAL FACTORS	2.8	7.4	7.5	11.3	2.2	9.5	3.8	4.5	4.1	4.4	4.6	6.2	6.1	1.0	1.4	6.5	16.7	138	16.7	1079.1	10.5%	38.7%	99.5%
EXPOSURE TO ELECTRICITY	19.3	16.9	15.9	16.1	29.0	25.8	24.9	27.7	23.1	19.6	11.1	10.2	18.3	27.1	26.9	6.6	2.4	256	29.0	581.7	18.6%	59.7%	100.0%
EXPOSURE TO CHEMICALS OR RADIATION	1.8	0.8	1.5	3.2	2.8	1.9	5.7	0.5	0.3	0.8	0.4	0.0	0.8	0.4	8.2	0.5	12.8	52	12.8	2863.8	4.1%	16.8%	86.6%
OTHER	20.4	18.3	11.9	20.2	24.8	9.5	34.7	73.8	30.8	17.6	16.9	16.5	6.1	5.6	34.4	15.6	42.1	384	73.8	387.8	26.6%	74.4%	100.0%

"Time at Risk Failure Model" for PPC's system (1993-2009)

High-risky sources (Q≥50%)

- Most important hazard source in PPC: "*EMPLOYEES FALLS*"
- Q=65.0% (for T=1 working week)
- Another high-risky hazard-source: "*IMPACTS ON STABLE OBJECTS*"
- Q=60.7% (for T=1 w.week).

Medium-risky sources (10%<Q<50%)

- Other significant hazard sources:
- "*COLLAPSES & SQUEEZES*" (Q=37.6% for T=1 w.week)
- "*OTHER SOURCES*" (Q=26.6%)
- "*EXPOSURE TO ELECTRICITY*" (Q=18.6%).

Low-risky sources (Q≤10%)

Other sources like

- "*EXPOSURE TO CHEMICALS OR RADIATION*" (Q=4.1%)
- "*EXTREME EFFORT*" (Q=9.4%)
- "*EXPOSURE TO NATURAL FACTORS*" (Q≅10%)

present a low (≤10%) or a very low (≤5%) probability of failure Q.

" TRF "

Risk-value **R** and its maximum value R_{max} , which have been calculated by applying the PRAT technique on the most important hazard sources defined in **PPC's** OHSS [**1993-2009**] **Probability of failure Q** of PPC's OHSS system by applying the "**Time at Risk Failure**" stochastic model, and using the total accidents and the corresponding **MTBF**

Hazard Sources	**Risk Value (R)**																	Total Accidents	**Max value of Risk** (R_{max})	**MTBF** [hr]	**Q** (%) *[T=1w. week]*	**Q** (%) *[T=1w. month]*	**Q** (%) *[T=1w. yr]*
(A)	**(B)**																	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1993-2009**	**1993-2009**	**1993-2009**			
EMPLOYEES FALLS	94.2	117.8	133.7	124.5	119.5	155.5	116.7	99.4	120.3	140.5	162.1	193.3	158.6	158.0	161.7	171.1	53.7	1303	193.3	114.3	65.0%	99.0%	100.0%
COLLAPSES & SQUEEZES	103.5	74.5	74.3	77.8	82.2	62.3	43.3	39.9	50.3	55.4	52.5	47.6	0.0	0.0	0.4	0.5	1.2	586	103.5	254.1	37.6%	87.5%	100.0%
IMPACTS ON STABLE OBJECTS	109.0	117.3	112.5	94.2	85.6	92.8	110.0	80.2	102.1	100.7	67.2	54.9	145.1	155.1	99.3	126.5	109.6	1159	155.1	128.5	60.7%	98.4%	100.0%
EXTREME EFFORT	12.3	11.3	7.7	8.7	9.4	6.0	0.3	1.7	2.7	4.2	3.5	3.0	7.0	4.5	1.1	8.5	1.9	123	12.3	1210.7	9.4%	35.3%	99.1%
EXPOSURE TO NATURAL FACTORS	2.8	7.4	7.5	11.3	2.2	9.5	3.8	4.5	4.1	4.4	4.6	6.2	6.1	1.0	1.4	6.5	16.7	138	16.7	1079.1	10.5%	38.7%	99.5%
EXPOSURE TO ELECTRICITY	19.3	16.9	15.9	16.1	29.0	25.8	24.9	27.7	23.1	19.6	11.1	10.2	18.3	27.1	26.9	6.6	2.4	256	29.0	581.7	18.6%	59.7%	100.0%
EXPOSURE TO CHEMICALS OR RADIATION	1.8	0.8	1.5	3.2	2.8	1.9	5.7	0.5	0.3	0.8	0.4	0.0	0.8	0.4	8.2	0.5	12.8	52	12.8	2863.8	4.1%	16.8%	86.6%
OTHER	20.4	18.3	11.9	20.2	24.8	9.5	34.7	73.8	30.8	17.6	16.9	16.5	6.1	5.6	34.4	15.6	42.1	384	73.8	387.8	26.6%	74.4%	100.0%

Joint evaluation of STODET

• The results of the PRAT and TRF application are **compatible** in general

For example:
Most important hazard sources:
"EMPLOYEES FALLS"
"IMPACTS ON STABLE OBJECTS"

• Both of the two models prove that **required actions** (or suppressive measures) are essential in a **medium-term** period (earlier than 1 w.year)

Risk-value **R** and its maximum value R_{max} , which have been calculated by applying the PRAT technique on the most important hazard sources defined in **PPC's** OHSS [**1993-2009**] **Probability of failure Q** of PPC's OHSS system by applying the "**Time at Risk Failure**" stochastic model, and using the total accidents and the corresponding **MTBF**

Hazard Sources	**Risk Value (R)**																	Total Accidents	**Max value of Risk** (R_{max})	**MTBF** [hr]	**Q** (%) *[T=1w. week]*	**Q** (%) *[T=1w. month]*	**Q** (%) *[T=1w. yr]*
(A)	**(B)**																	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1993-2009**	**1993-2009**	**1993-2009**			
EMPLOYEES FALLS	94.2	117.8	133.7	124.5	119.5	155.5	116.7	99.4	120.3	140.5	162.1	193.3	158.6	158.0	161.7	171.1	53.7	1303	193.3	114.3	65.0%	99.0%	100.0%
COLLAPSES & SQUEEZES	103.5	74.5	74.3	77.8	82.2	62.3	43.3	39.9	50.3	55.4	52.5	47.6	0.0	0.0	0.4	0.5	1.2	586	103.5	254.1	37.6%	87.5%	100.0%
IMPACTS ON STABLE OBJECTS	109.0	117.3	112.5	94.2	85.6	92.8	110.0	80.2	102.1	100.7	67.2	54.9	145.1	155.1	99.3	126.5	109.6	1159	155.1	128.5	60.7%	98.4%	100.0%
EXTREME EFFORT	12.3	11.3	7.7	8.7	9.4	6.0	0.3	1.7	2.7	4.2	3.5	3.0	7.0	4.5	1.1	8.5	1.9	123	12.3	1210.7	9.4%	35.3%	99.1%
EXPOSURE TO NATURAL FACTORS	2.8	7.4	7.5	11.3	2.2	9.5	3.8	4.5	4.1	4.4	4.6	6.2	6.1	1.0	1.4	6.5	16.7	138	16.7	1079.1	10.5%	38.7%	99.5%
EXPOSURE TO ELECTRICITY	19.3	16.9	15.9	16.1	29.0	25.8	24.9	27.7	23.1	19.6	11.1	10.2	18.3	27.1	26.9	6.6	2.4	256	29.0	581.7	18.6%	59.7%	100.0%
EXPOSURE TO CHEMICALS OR RADIATION	1.8	0.8	1.5	3.2	2.8	1.9	5.7	0.5	0.3	0.8	0.4	0.0	0.8	0.4	8.2	0.5	12.8	52	12.8	2863.8	4.1%	16.8%	86.6%
OTHER	20.4	18.3	11.9	20.2	24.8	9.5	34.7	73.8	30.8	17.6	16.9	16.5	6.1	5.6	34.4	15.6	42.1	384	73.8	387.8	26.6%	74.4%	100.0%