Modeling Human Actions as a Dynamic Process in the Context of External and Internal Hazards

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- Dependencies and Interactions affecting action sequences - influence on human reliability
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  - aleatory uncertainties
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  - stress behavior
- Example Result of Application

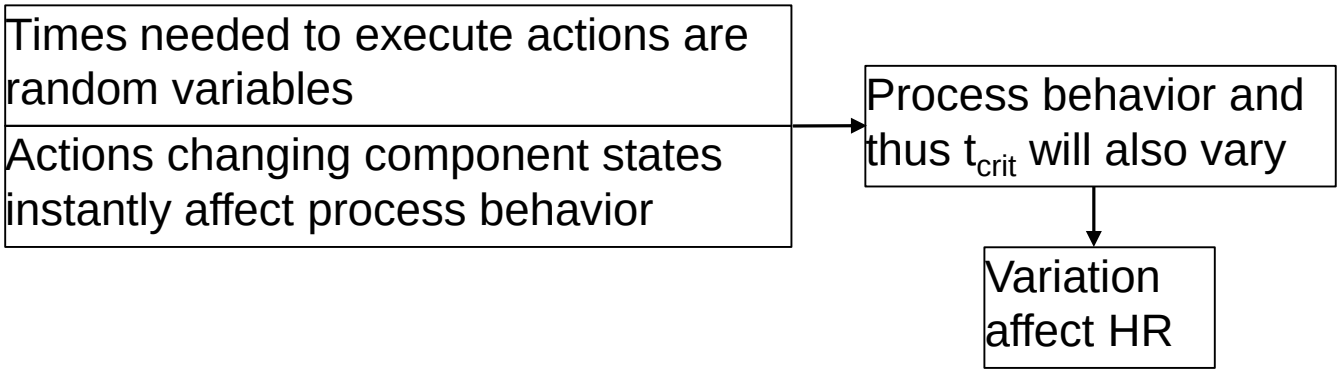
Complexity arising in case of External / Internal Hazards

- External and internal hazards may
  - cause various impacts on the plant
  - lead to cascading effects increasing the problems to deal with
- Human actions (HA) are required to prevent or mitigate harmful consequences
- Situations from unforeseen impacts are unfamiliar and unexpected to personnel constituting a complex problem to be solved
  - knowledge based behavior is required where novel strategies have to be conceived and applied
- A human procedure is characterized by dependencies and interactions
  - causing different action sequences to be executed
  - influence human reliability

Interdependency of Human Reliability (HR) and Time Effects:

- Reliability of a human procedure depends
  - on the correct execution of actions and
  - on the time when actions are accomplished

- The required time t_{crit} until HA must be accomplished to be a success is determined by process behavior



★ **Time is an important factor to be considered in HRA** ★

Dependency of Human Actions on System/Process States:

HA not only affect system states but system states may also affect sequences of HA

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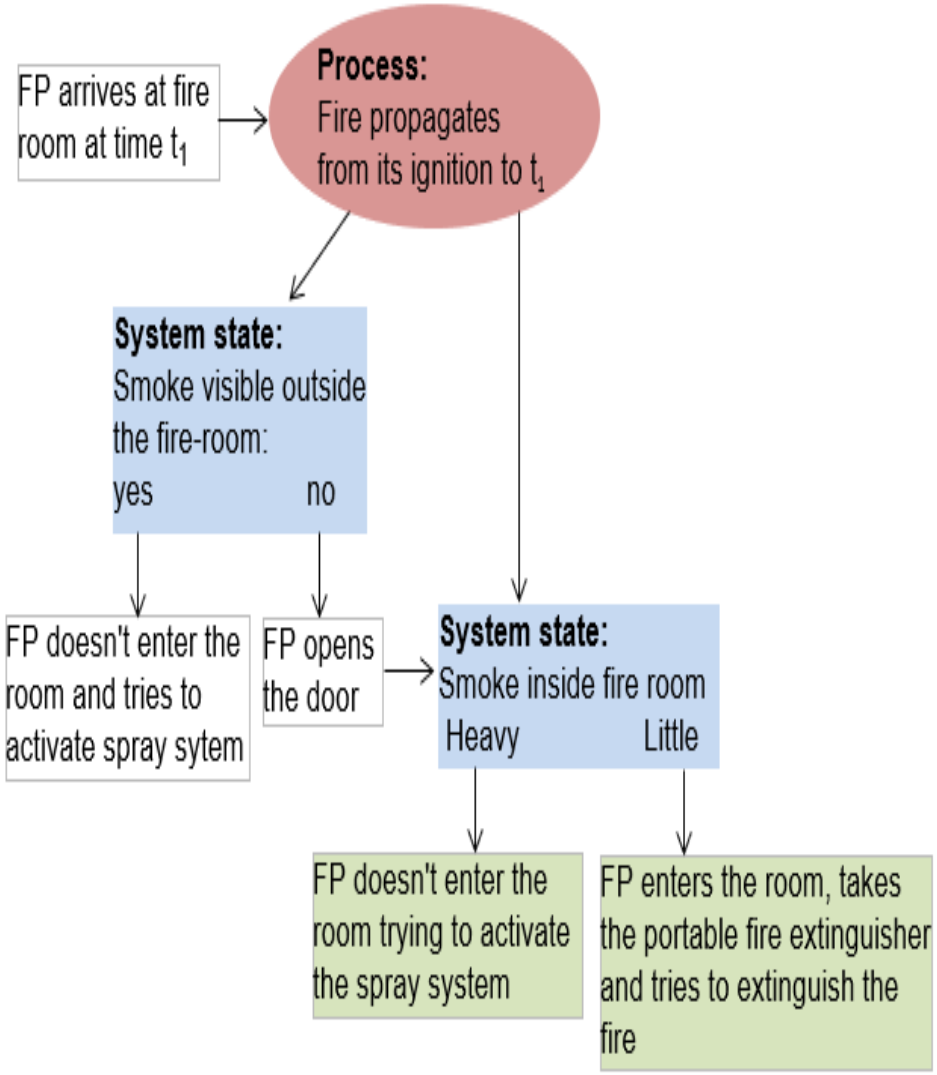
Different action sequences affect

- times when actions are accomplished
- means of fire extinguishing

↓

Influence success of the procedure



Dependency of Human Actions on Stochastic Influences:

Sequences of HA depend on realizations of random events

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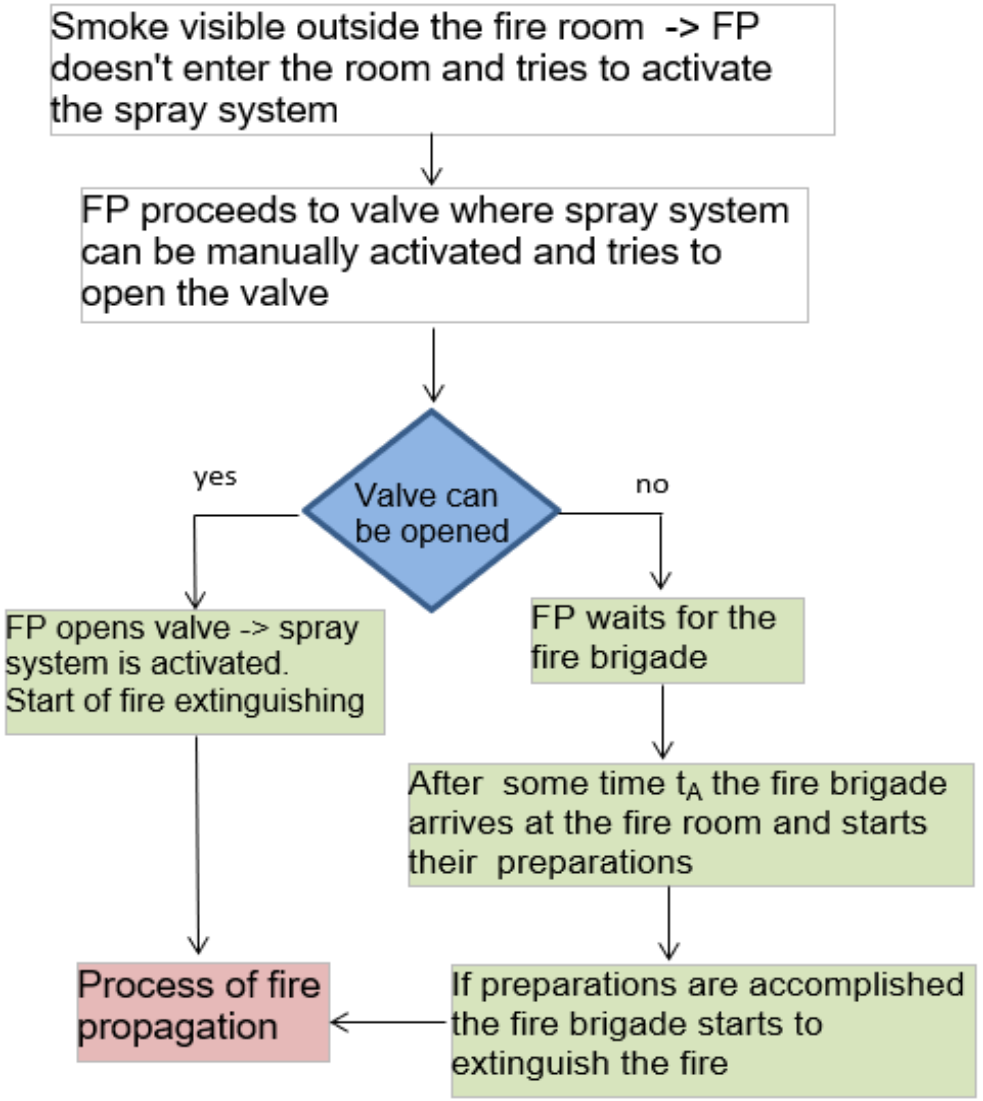
Different sequences of HA

- cause different times when actions are accomplished
- affect success of the procedure



Aspects of Modeling Stress in HRA

- Stress is a dynamic quantity which may increase (decrease) depending on
  - system and plant conditions
  - complexity of tasks to be solved
  - success or failure of previous actions

- Behavior of stress is related to individuals in given situations
  - some may develop high stress while others may not

- Uncertainty exist
  - if stress increases in given situations
  - what decisions are made under high stress -> error of commission

Crew-Module

- To consider time effects and dependencies advanced methods in human reliability analysis are required

- A method was developed (Crew-Module)
  - to model and simulate a human procedure as dynamic event sequences
  - to consider dependencies of action sequences on
    - time effects
    - stochastic influences (aleatory uncertainties)
    - system/process states
    - stress behavior

Application Example: Fire-Fighting Procedure

Different action sequences depending on

aleatory uncertainty, e.g.:

- correct or false info about fire room
- stress increase in case of false info
- reliability of technical equipment

process state, e.g.:

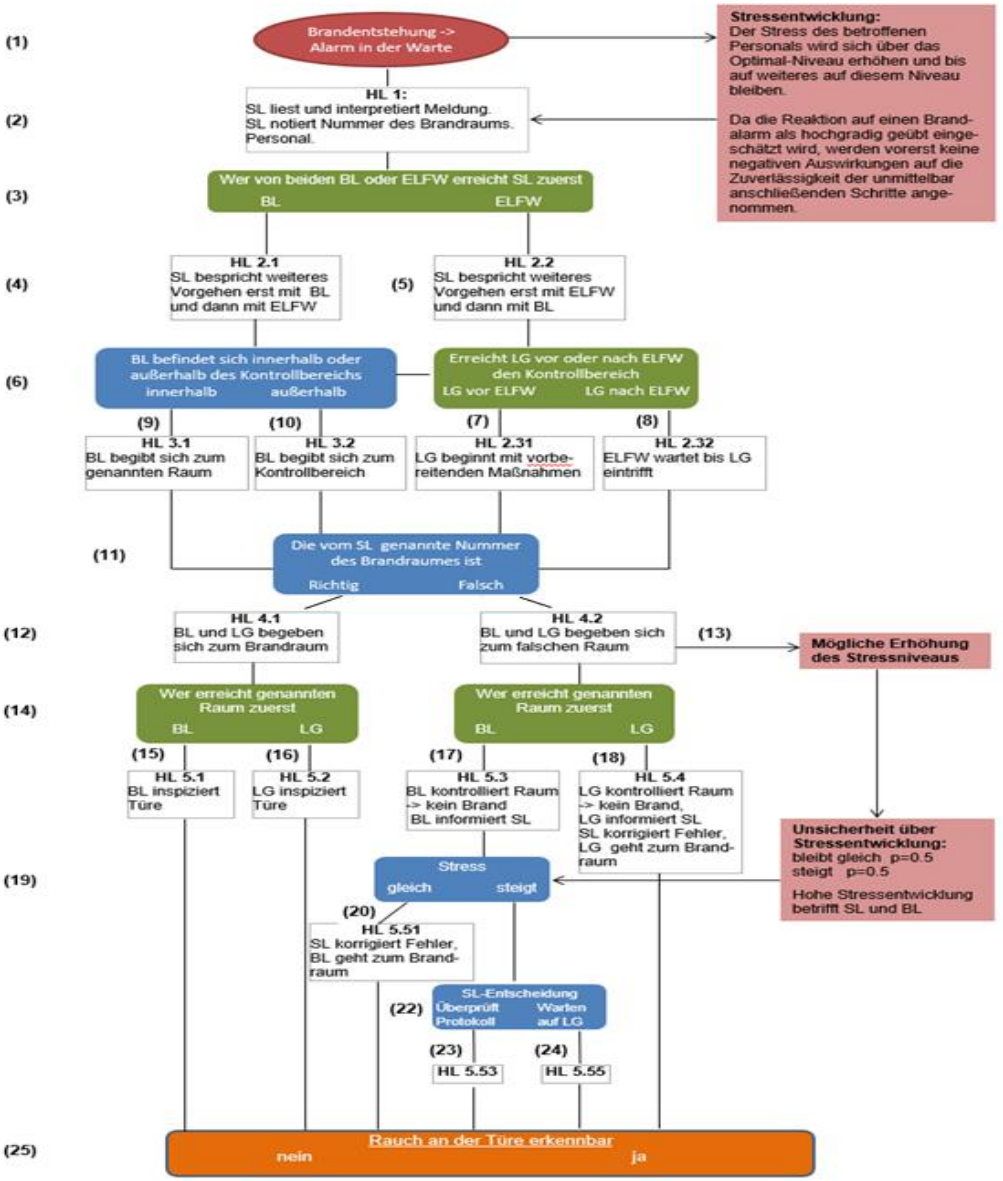
- smoke situation in fire room

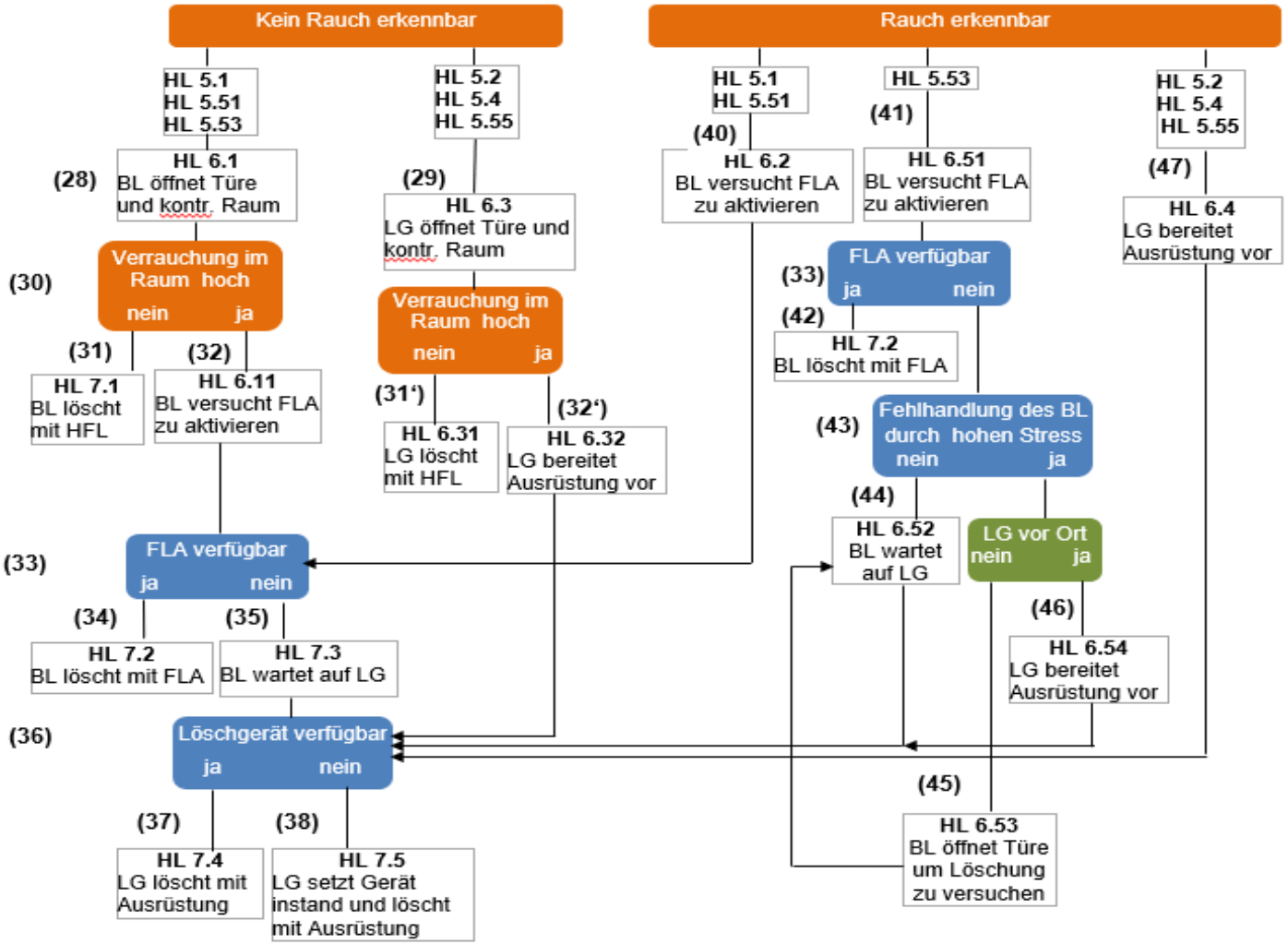
time effects, e.g.:

- who reaches fire room first

aspects of stress, e.g.:

- stress of FP and SV increase if false information about fire room is realized
- alternative decisions under high stress




Kein Rauch erkennbar
Rauch erkennbar
HL 5.1
HL 5.51
HL 5.53
HL 5.2
HL 5.4
HL 5.55
HL 5.1
HL 5.51
HL 5.53
HL 5.2
HL 5.4
HL 5.55
(28)
HL 6.1
BL öffnet Türe und kontr. Raum
(29)
HL 6.3
LG öffnet Türe und kontr. Raum
(40)
HL 6.2
BL versucht FLA zu aktivieren
(41)
HL 6.51
BL versucht FLA zu aktivieren
(47)
HL 6.4
LG bereitet Ausrüstung vor
(30)
Verrauchung im Raum hoch
nein ja
Verrauchung im Raum hoch
nein ja
(33)
FLA verfügbar
ja nein
(31)
HL 7.1
BL löscht mit HFL
(32)
HL 6.11
BL versucht FLA zu aktivieren
(31‘)
HL 6.31
LG löscht mit HFL
(32‘)
HL 6.32
LG bereitet Ausrüstung vor
(42)
HL 7.2
BL löscht mit FLA
(43)
Fehlhandlung des BL durch hohen Stress
nein ja
(33)
FLA verfügbar
ja nein
(44)
HL 6.52
BL wartet auf LG
LG vor Ort
nein ja
(34)
HL 7.2
BL löscht mit FLA
(35)
HL 7.3
BL wartet auf LG
(46)
HL 6.54
LG bereitet Ausrüstung vor
(36)
Löschgerät verfügbar
ja nein
(45)
HL 6.53
BL öffnet Türe um Löschung zu versuchen
(37)
HL 7.4
LG löscht mit Ausrüstung
(38)
HL 7.5
LG setzt Gerät instand und löscht mit Ausrüstung

Result: Quantifying the effect of false information and high stress

case1: SV gives correct information
case2: false info & normal stress
case3: false & high stress & right decision
case4: false & high stress & wrong decision

Mean Time of Fire Ext. (min)

case1:	9.5	**5%: 7.5**	**95%: 12.5**
case2:	15.3	**5%: 11.7**	**95%: 18.8**
case3:	16.1	**5%: 12.4**	**95%: 19.5**
case4:	23.4	**5%: 20.2**	**95%: 26.1**

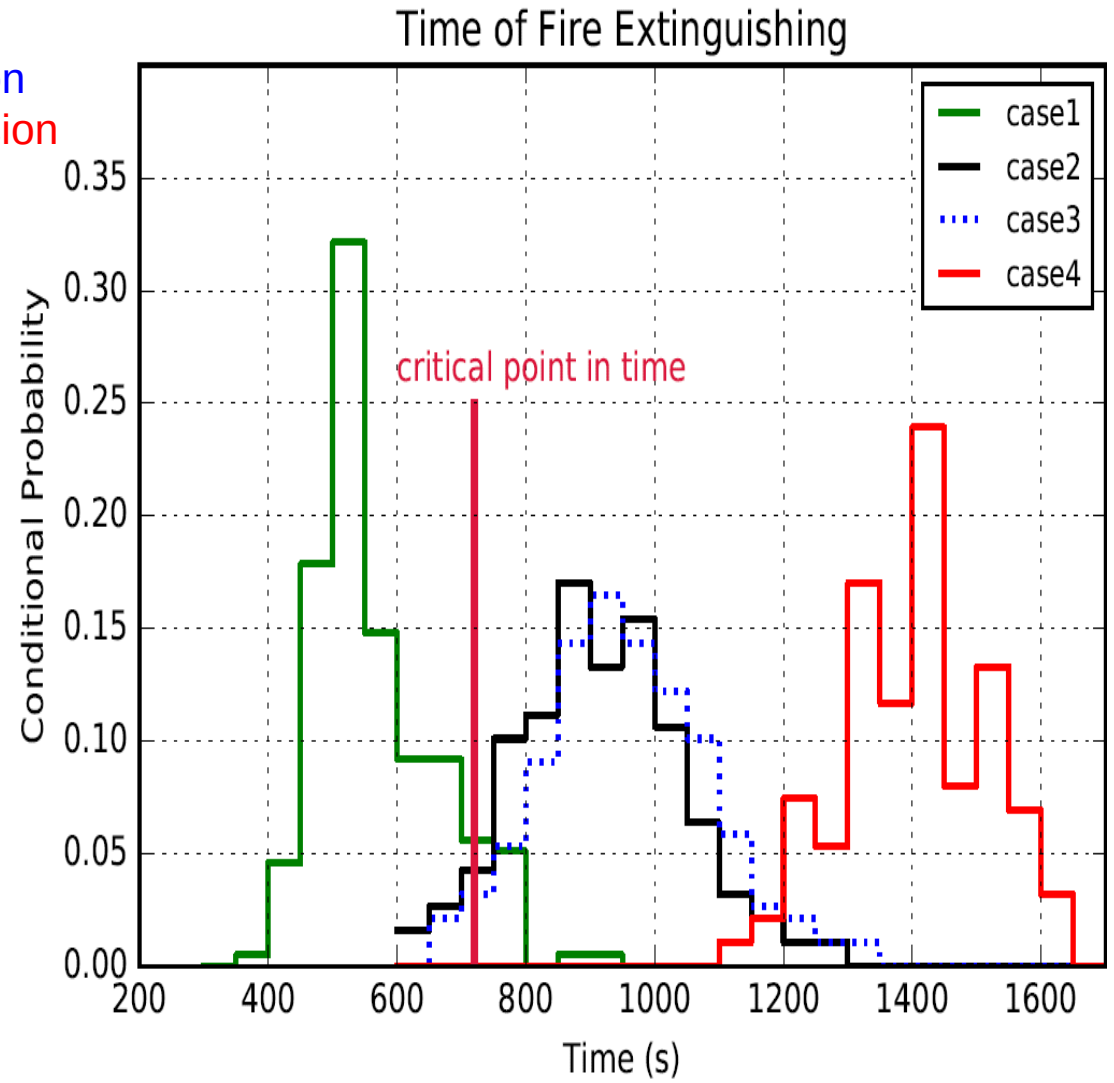
Assume: t_{crit} = 12 min:

P (success | case1) = 0.9

P (success | case2) = 6.2E-02

P (success | case3) = 3.7E-02

No success if wrong decision is made due to high stress **P(case4) = 1.4E-04**



Conclusion:

- Dependencies and time interactions are relevant issues influencing the success of a human procedure
- To consider dependencies and time interactions advanced methods of dynamic HRA are required
- At GRS a method was developed
  - to model and simulate human procedures as dynamic event sequences
  - dependencies, time interactions and stress can be considered
- The approach was applied to a fire-fighting procedure and can be used
  - to calculate time distributions of relevant actions
  - to quantify the effect of random events or stress on HR