Analysis of the risks faced by waste management following flash floods

Valencia DANA as a case study

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Objectives
Methodology
Results
- List of Failure Modes & Categorization
- Experts' evaluations
- Risk Priority Number & Hierarchy

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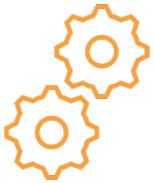
Key recommendations
Universities and Research Centers' Roles

Introduction

- Waste generation after a natural disaster has been traditionally overlooked and underestimated.
  - In the state of the art of the effects after flood disasters, waste generation does not appear among them.
  - After setting up a commission of experts, the city council of Valencia drew up 100 urgent actions after the 2024 floods: None of them related to waste management
- Research interest in DWM has grown in just the last 10-15 years
- Only a few recent papers highlight the relevance of proper DWM.
- No scientific contribution assesses the effects floods have on waste management systems.

Objective

Identify and prioritize failure modes that might put waste management at risk following extreme flooding.

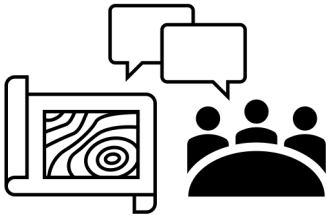


Failure Mode and Effects Analysis (FMEA).

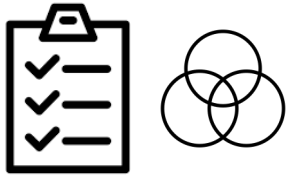
Risk Priority Number

Valencia DANA in October 2024 as a case study

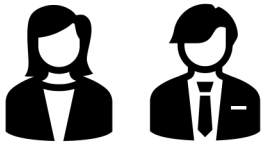
Methodology



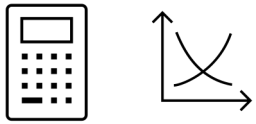
1. Visit to affected areas, interviews, workshops, state-of-the-art review



2. List of FM & Categorization



3. $Experts$ FM $rating$ $(1-10$ points$)$



4. Average of each factor
and
calculation of RPN = (S x O x T)

Severity: from no danger to very high

Occurrence: from low probability to almost certain

Temporality: short-medium-long term

Results

- Fifty-two failure modes were identified and grouped into three categories:
  - **Planning and Management (P&M)** - 21 FMs (P&M_1, P&M_2……..P&M_21)
  - **Infrastructure and Logistics (I&L)** - 15 FMs (I&L_1, I&L_2…….I&L_15)
  - **Environmental and Social (E&S)** - 16 FMs (E&S_1, E&S_2…… E&S_16)

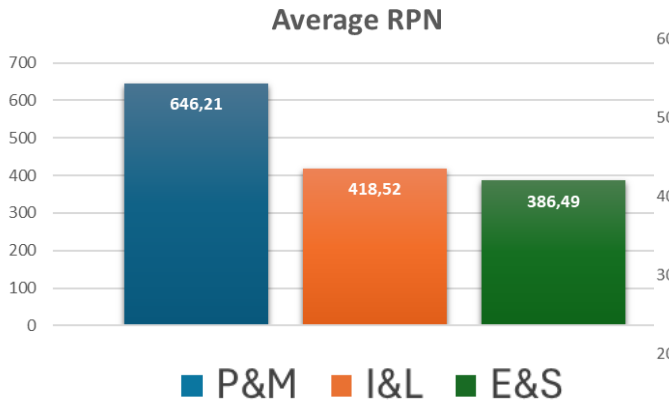
RPN: FM hierarchy

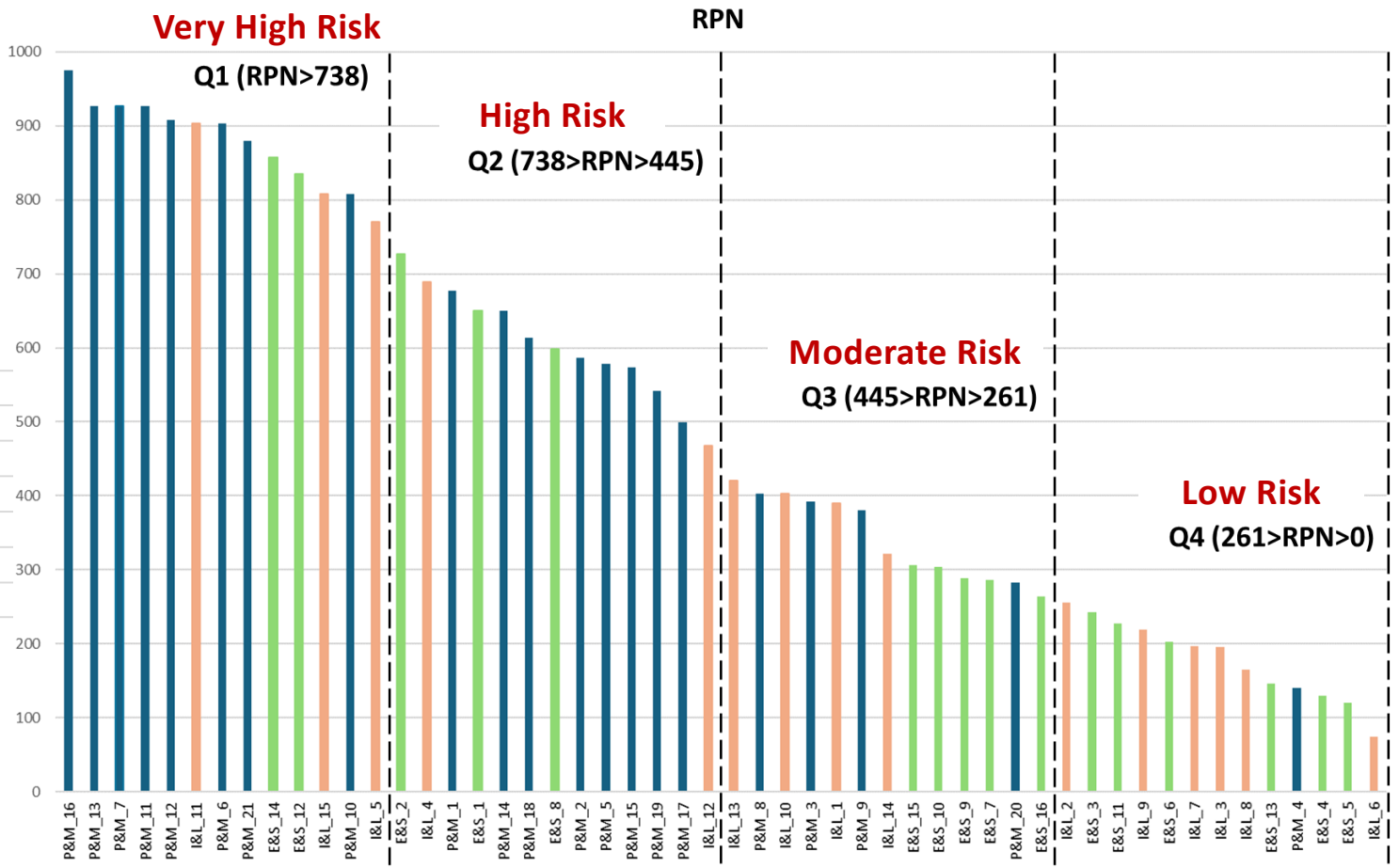
RPN quartiles were calculated to set risk levels

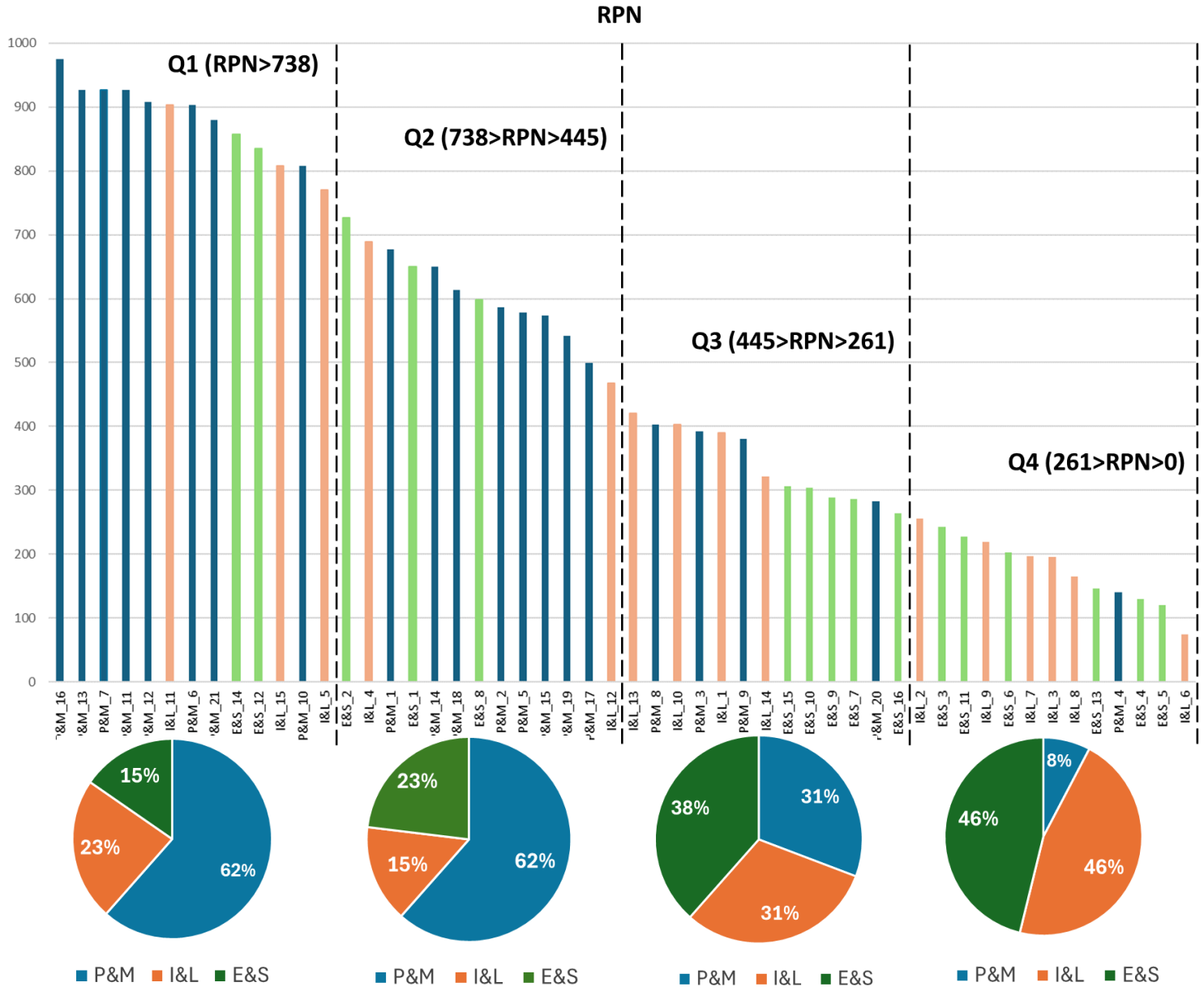
P75=737,6

P50=444,4

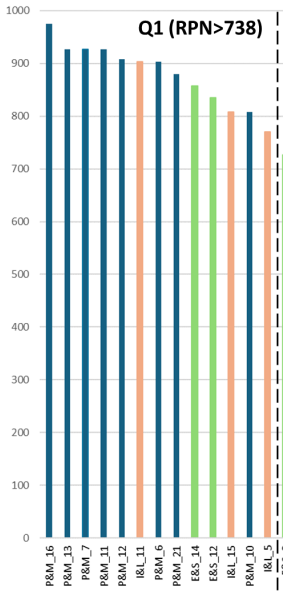
P25=261,2

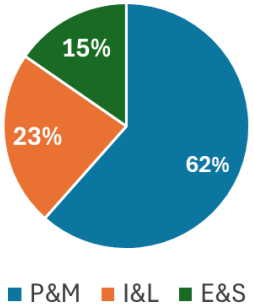





RPN
Q1 (RPN>738)
Q2 (738>RPN>445)
Q3 (445>RPN>261)
Q4 (261>RPN>0)
1000
900
800
700
600
500
400
300
200
100
0
15%
23%
62%
23%
15%
62%
38%
31%
31%
8%
46%
46%
P&M
I&L
E&S

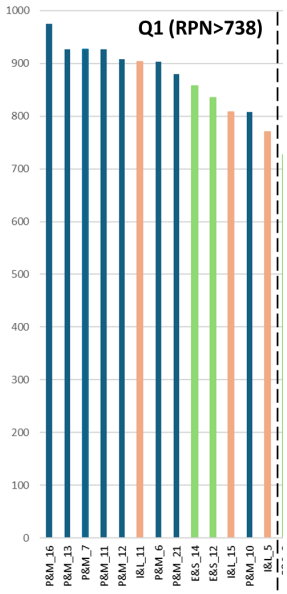
RPN: FM hierarchy Q1 (Very High Risk)

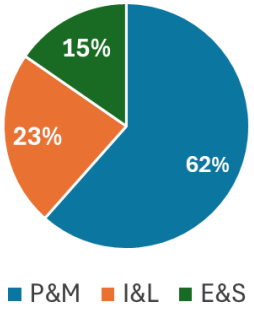




FM Code	FM description (Q1)	RPN
P&M_16	Not including disaster waste management in the emergency management	975,2
P&M_13	Lack of coordination with specialized services for disposing of hazardous waste/dangerous substances	926,4
P&M_7	Low accessibility of data and information	926,3
P&M_11	Lack of evaluation of the types of waste to be managed	926,3
P&M_12	Poor information about the description of the general terrain types, land use, and accessibility for the areas impacted and how that may affect DWM operations.	907,7
I&L_11	Insufficient landfill capacity	903,2
P&M_6	Poor/lack of enforcement by the government of legal instruments	903,1
P&M_21	Lack of Monitoring Debris Operations	879,9
E&S_14	Excessive amounts of sludge deposited on crops	857,4
E&S_12	Excessive sludge deposition in the lagoon or protected areas	834,8
I&L_15	Poor management of wrecked vehicles: no hazardous waste removal, stacking, lack of sorting, etc.	808,0
P&M_10	Lack of regulations/ acts and guidelines	807,5
I&L_5	Lack of heavy equipment (dump trucks, bulldozers, shredders, grapplers) and other essential resources	770,1

RPN: FM hierarchy Q1 (Very High Risk)

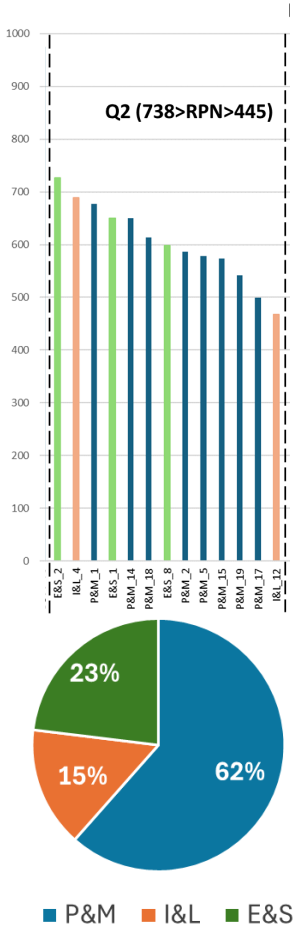




P&M	No presence of WM experts in the Emergency Team Lack of coordination with hazardous services Lack of data and information (Affected areas, type of waste…) Lack of control, regulations & legal support
I&L	Insufficient landfill capacity Poor management of wrecked vehicles Lack of machinery and resources
E&S	Sludge deposition in crops, lagoon, and protected areas

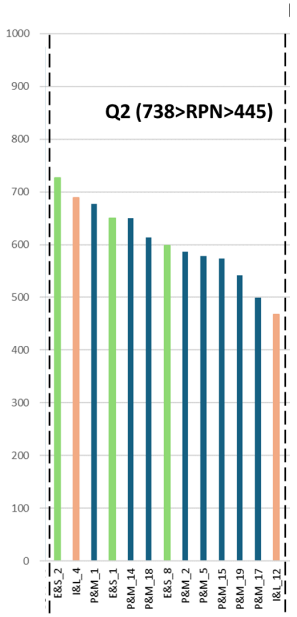
FMs in Q1 are related to the **lack of planning of the first stages of the crisis response (Emergency),** where **confusion, misinformation, uncertainty, and lack of coordination** prevail.

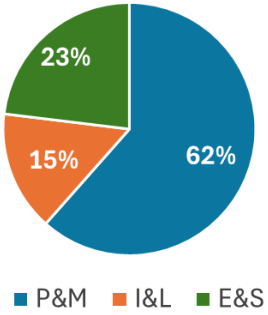
RPN: FM hierarchy Q2 (High Risk)



FM Code	FM description (Q2)	RPN
E&S_2	Having waterways, agricultural areas, and communities contaminated by chemicals and heavy metals	726,8
I&L_4	Lack of enough landfill equipment and machinery to face the high volume of DWM	688,5
P&M_1	Choosing inappropriate locations for temporary staging sites	676,9
E&S_1	Hazardous waste enters the soil and groundwater	650,3
P&M_14	Lack of fluid collaboration among all levels of government regarding DWM	649,7
P&M_18	Ill-defined roles and responsibilities among stakeholders	614,1
E&S_8	Residents and volunteers' unawareness of safety rules, measures, and procedures to protect themselves from DWM perils	598,5
P&M_2	Improper estimation of the total post-flood volume of DW generated	586,6
P&M_5	Poor/lack of coordination and integration among top management	578,0
P&M_15	Lack of coordination and synergy among all DWM agents	573,8
P&M_19	Performing outside the regulatory framework to speed up DW removal	541,9
P&M_17	Having difficulties hiring external contractors to provide additional labor and equipment	498,8
I&L_12	Block drain infrastructure	468,0

RPN: FM hierarchy Q2 (High Risk)

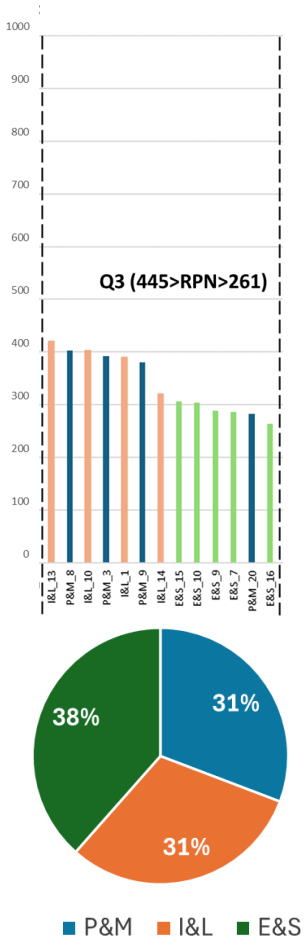




P&M	Choosing inappropriate locations for temporary staging sites Lack of collaboration among goverment levels, stakeholders, external contractors & top management Ill-defined roles and responsibilities among stakeholders Improper estimation of the total post-flood volume of waste Performing outside the regulatory framework to speed up DW removal
E&S	Soil and water contamination by hazardous substances Residents and volunteers lack of knowledge about how to deal with waste
I&L	Lack of landfill equipment and machinery Block drain infrastructure

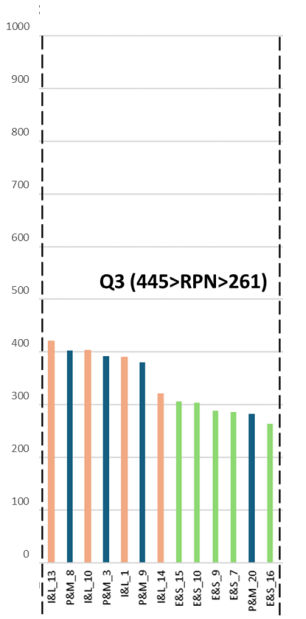
FMs **in Q2** are **key during the early response** phase, a few weeks after the disaster, **when the strategy and the operational plan must be designed.**

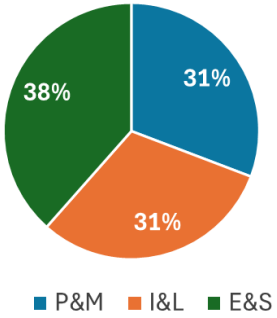
RPN: FM hierarchy Q3 (Medium Risk)



FM Code	FM description (Q3)	RPN
I&L_13	Lack/low consideration of the impact of post-disaster conditions on the transport network	420,8
P&M_8	Having imposed time constraints on DW removal and disposal	403,0
I&L_10	Technical constraints/ insufficient equipment, machinery, and workforce with the latest technology	402,2
P&M_3	Having and communicating insufficient disaster and debris operations information	391,9
I&L_1	Inability to use the facilities' full capacity	390,0
P&M_9	Insufficient funds and finance allocated	380,3
I&L_14	Suffering from a fire in the temporary sites or fields of stacked vehicules	321,8
E&S_15	Suffering trauma or injuries after disaster	306,0
E&S_10	DW Visual impact	304,0
E&S_9	Underestimating Environmental Considerations and other Regulatory Requirements	289,0
E&S_7	Disrupting the lives of residents near the temporary debris management sites	286,0
P&M_20	Ill-defined priorities during both the response and recovery phase operations	282,6
E&S_16	Increasing mental health cases	263,3

RPN: FM hierarchy Q3 (Medium Risk)

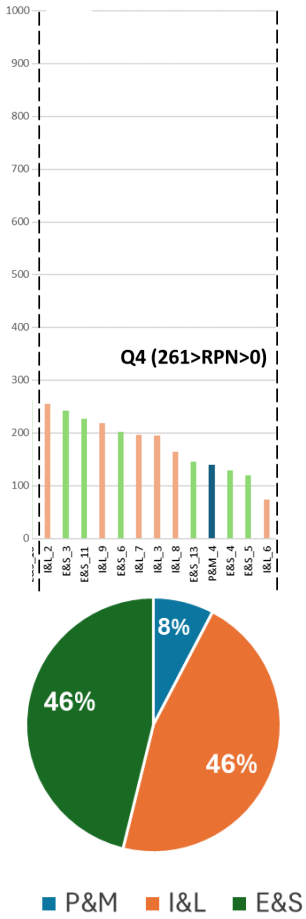




E&S	Mental health disorders, trauma/injuries, and discomfort Underestimating Environmental Considerations and other Regulatory Requirements
I&L	Unexpected post-disaster problems on the transport network Technical constraints/ insufficient equipment, machinery, and workforce Suffering from a fire in the temporary storage sites
P&M	Having imposed time constraints on DW removal and disposal Insufficient funds, monitoring, information, and communication Ill-defined priorities in DWM operations

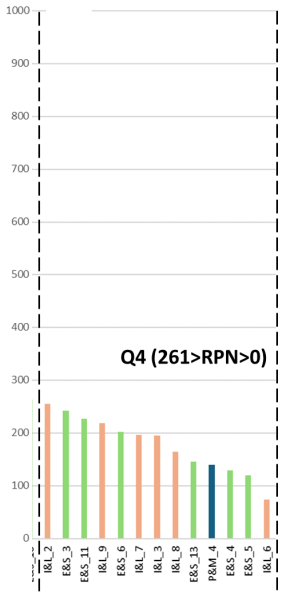
In Q3, FMs are related to the recovery phase. E&S risks are more prevalent because **the amount of waste is already visible, accidents occur, and people fear for their health and the environment's safety.**

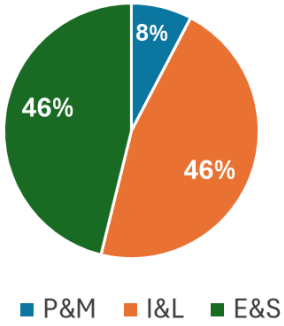
RPN: FM hierarchy Q4 (Low Risk)



FM Code	FM description (Q4)	RPN
I&L_2	Non-operational waste facilities due to power outages	255,0
A&S_3	Transporting hazardous materials that endanger the health of workers and people in the area	242,3
A&S_11	Deficient management of pruning waste, reeds, and logs in the lagoon and beaches	226,9
I&L_9	Uncollected building and construction waste hindering reconstruction	219,4
A&S_6	Mixing hazardous and toxic wastes such as asbestos in damaged buildings and its reuse: health risks associated with inhalation and contact	202,5
I&L_7	Waste collection routing mistakes	196,6
I&L_3	Non-operational facilities due to flooded access	195,0
I&L_8	Landfills cut off by road and transport routes	165,0
A&S_13	Flood-induced microplastic mobilization from WM facilities	146,3
P&G_4	DWM delayed by giving priority of road use to emergency services (affecting WM time and cost)	140,6
A&S_4	Breeding sites for rodents, mosquitoes, arbovirus transmission, and contagious disease vectors (Causing viral diseases and potential infection)	130,0
A&S_5	Serious health risks to residents, including inhalation of dust, odor, and noise	120,0
I&L_6	Access routes and roads blocked and/or damaged	74,4

RPN: FM hierarchy Q4 (Low Risk)





I&L	Non-operational waste facilities due to power outages, flooded access or bloqued roads Waste collection routing mistakes Access routes and roads blocked and/or damaged Uncollected building and construction waste hindering reconstruction
E&S	Deficient management of pruning waste, reeds, and logs in the lagoon and beaches Serious health risks to residents, including viral diseases and potential infection, inhalation of dust, odor, and noise Flood-induced microplastic mobilization from WM facilities
P&M	DWM delayed by giving priority of road use to emergency services (affecting time and cost)

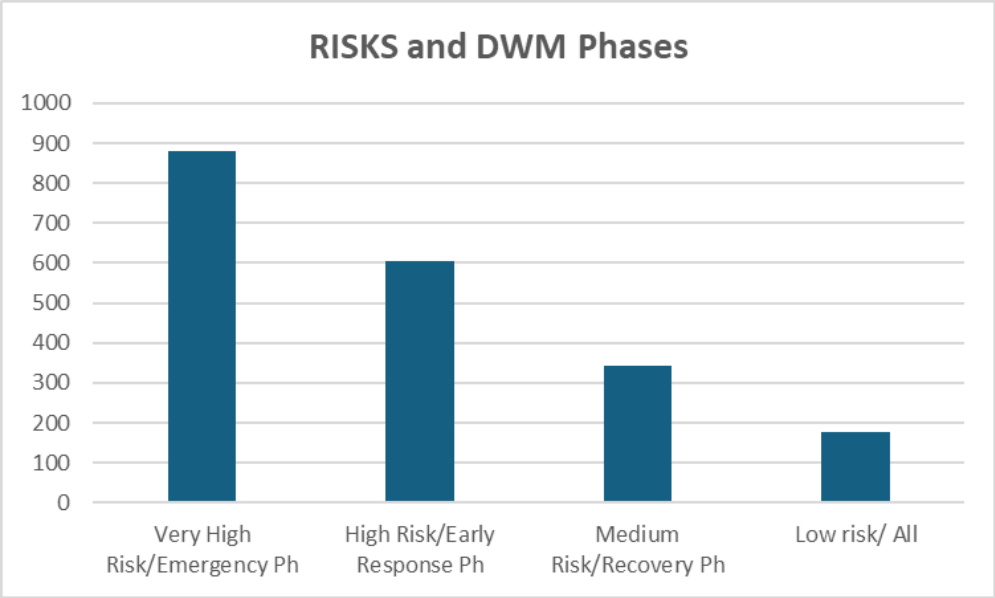
The FMs in Q4, despite being important, **had low scores in some of the Severity, Occurrence, and Temporality factors. FMs belonging to the I&L category were resolved quickly, and those to the E&S category did not occur in Valencia.**

Conclusions

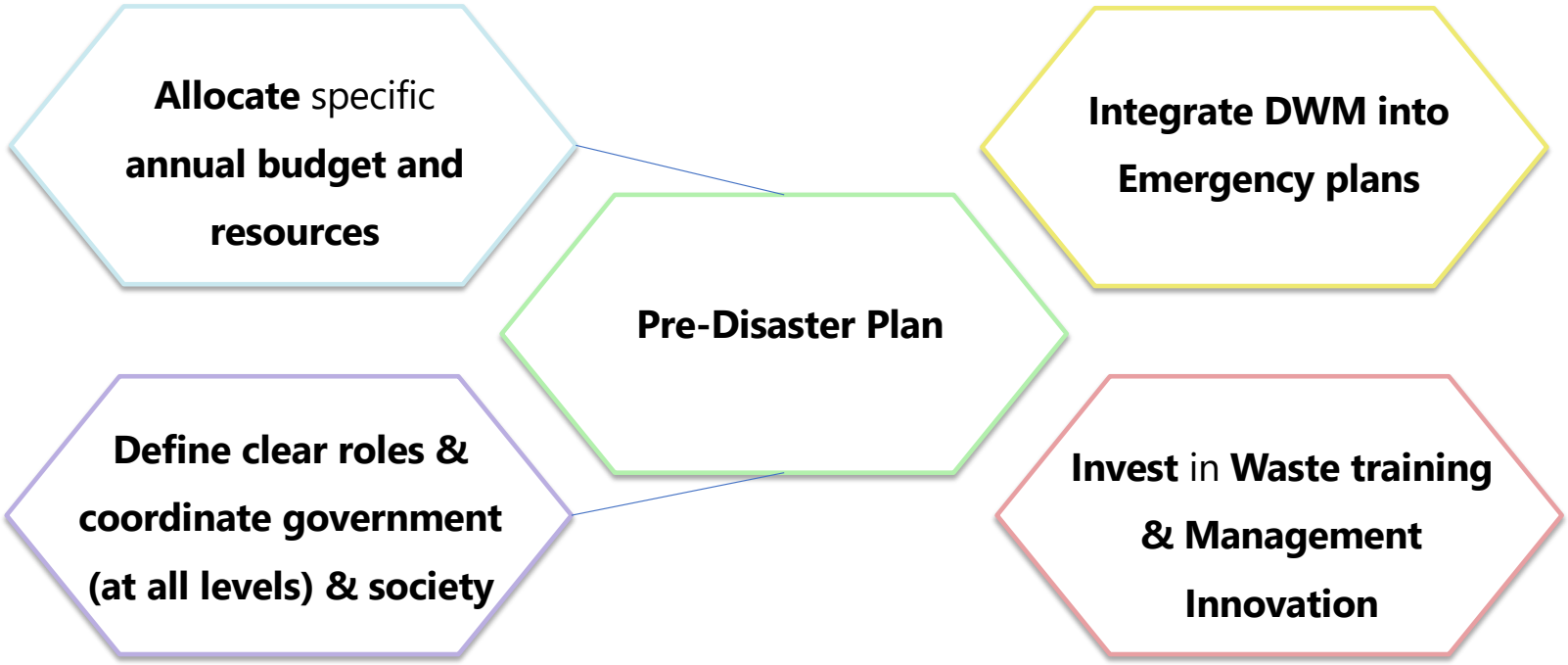
- FMs in the **Planning & Management category are the riskiest**
- **Lack of planning leads to inefficiency and chaos, increases costs, harms human health and the environment, and hampers recovery from the crisis.**
- **Managerial issues are crucial** to risk mitigation in the DWM

Conclusions

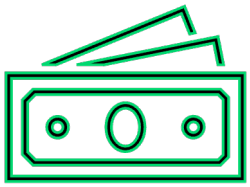
- **Risk analysis shows the highest risks are related to the early DWM phases**, which are more complex when no pre-disaster plans exist.



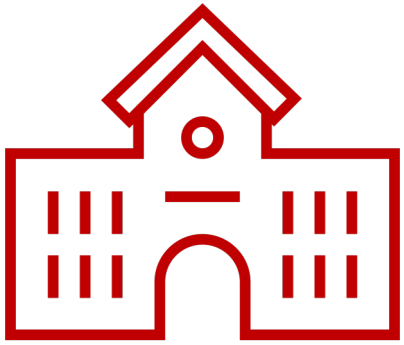
Key recommendations

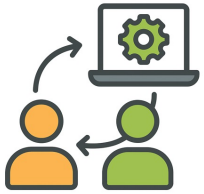


Role of Research Centers and Universities



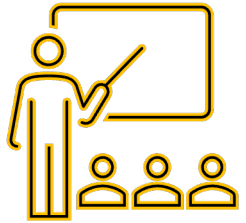
Raise funds





Technology and knowledge transfer

Interdisciplinarity



Training and Capacity Building

Analysis of the risks faced by waste management following flash floods

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