Extending the I-95 Rule-based Incident Duration System with an Automated Knowledge Transferability Model

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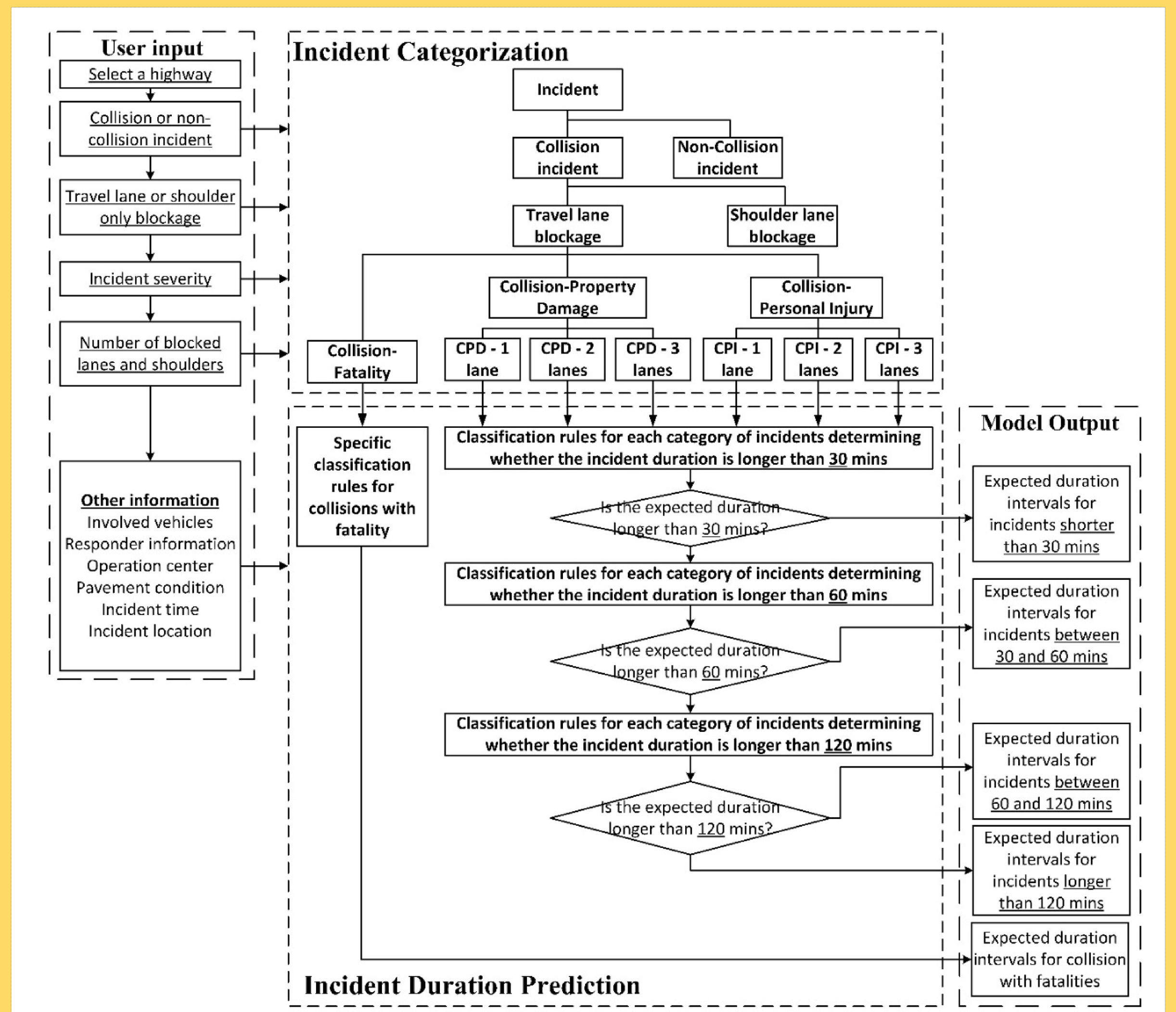
Abstract

- The rule-based incident duration prediction model (IDPM), covering I-95, I-495, and I-695, has been adopted by MDOT SHA in daily responses to non-recurrent congestion.
- In light of its effectiveness and robustness in practice, expanding such a system to all other highway emerges as a desirable but challenging task due to:
  - ❑ The need of integrating field operators' expertise in generating prediction rules
  - ❑ The dependence of sufficient incident records for key parameter calibration
- To circumvent such a data-demanding and time-consuming process for extending IDPM's spatial coverage, this study has proposed a Knowledge Transferability Analysis (KTA) method, featuring its automated process to assess, select, and transfer existing prediction rules to perform incident duration estimate for the new target highway
- Evaluation of the proposed KTA with the incident records from **Maryland I-70** reveals that it can achieve the accuracy of 87% with the training dataset (i.e., 2016-2018) and of 82% with the test dataset (i.e., 2019), comparable to the current system's performance but demanding much fewer incident records for model calibration and significantly fewer efforts for system expansion

Knowledge-based System

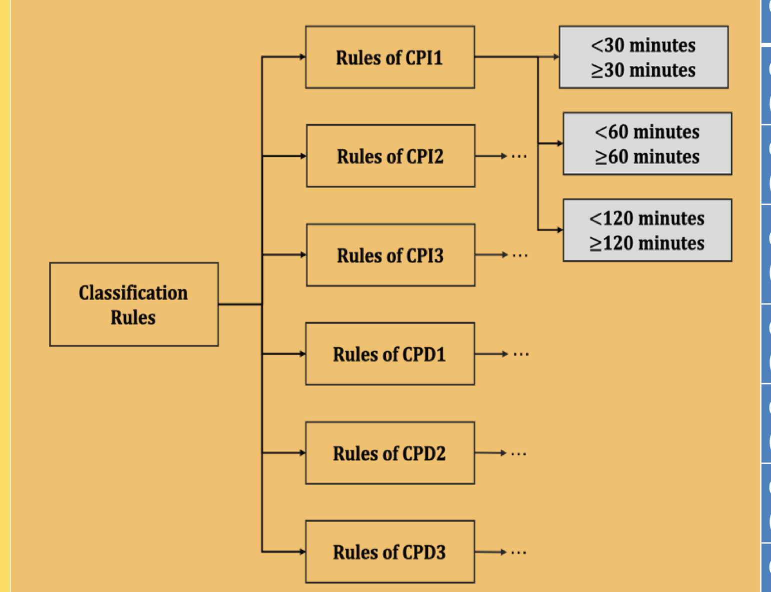


The application process of the developed IDPM-I-95 software

Knowledge Transferability Analysis (KTA)

Rule Box Generation and Update

The function of the Rule Box is to house all effective prediction rules from existing IDPMs (i.e., I-95, I-495, and I-695). Such rules in each category are further divided into three types based on their pre-specified thresholds for classifying incident duration



Ranking of key factors

The rule transferring priority determines not only which rules to transfer but also the execution structure of the new IDPM. Before assessing the transferability priority for each set of rules in the Rule Box, all key factors are initially classified into seven categories

Category	Description
Category-1 (# of responders)	the number of different responders at the incident scene
Category-2 (First arrived responder)	type of the first-arriving responders
Category-3 (Vehicle status)	the number and the type of vehicles involving in incidents and their damage levels
Category-4 (Pavement conditions)	indicators for the pavement conditions
Category-5 (Lane blockage)	indicators to denote the lane-blockage conditions
Category-6 (Operation center)	indicators reflecting different incident response centers
Category-7 (Time)	temporal-related indicators associated with an incident

Transferability Ranking Analysis

- ***Transferability Ranking-I Analysis:***

Using Random forest to identify the relative impacts of seven categories of factors on the resulting incident durations revealed in the target new system's incident records

- ***Transferability Ranking-II Analysis:***

Using Data Envelopment Analysis (DEA) to rank the importance associated with categories of factors from the perspective of how often they have been used in the existing prediction rules and the resulting effectiveness

- ***Transferability Ranking Integration***

Employing the method for rank aggregation to produce final optimized ranking list for all categories

$$Min \sum_{i=1}^{7} \left(|\delta_i^* - r_i^1| + |\delta_i^* - r_i^2| \right) \times w_i$$

δ_i^* is the optimal rank for category i; r_i^1 and r_i^2 are the resulting ranks from Rank-I and Rank-II test for category i; and w_i stands for the number of existing rules using one or more factors from category i.

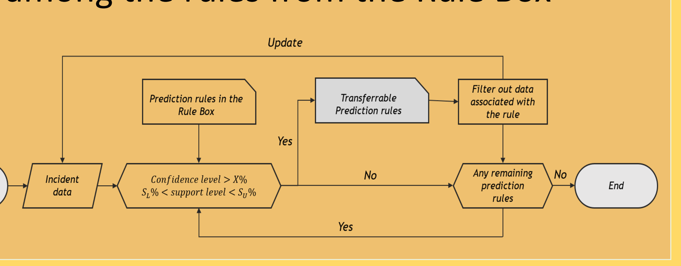
Prioritizing Candidate Rules

All rules based on their logic structure and target incident types are assigned with a customized score with following regulations

- *Take optimized rankings as grades*
- *The rule combined by "AND", sum up the grade*
- *The rule combined by "OR", take the minimum combination and add 100*
- *The rule for estimating incident durations of <30, <60, or <120, add 200*

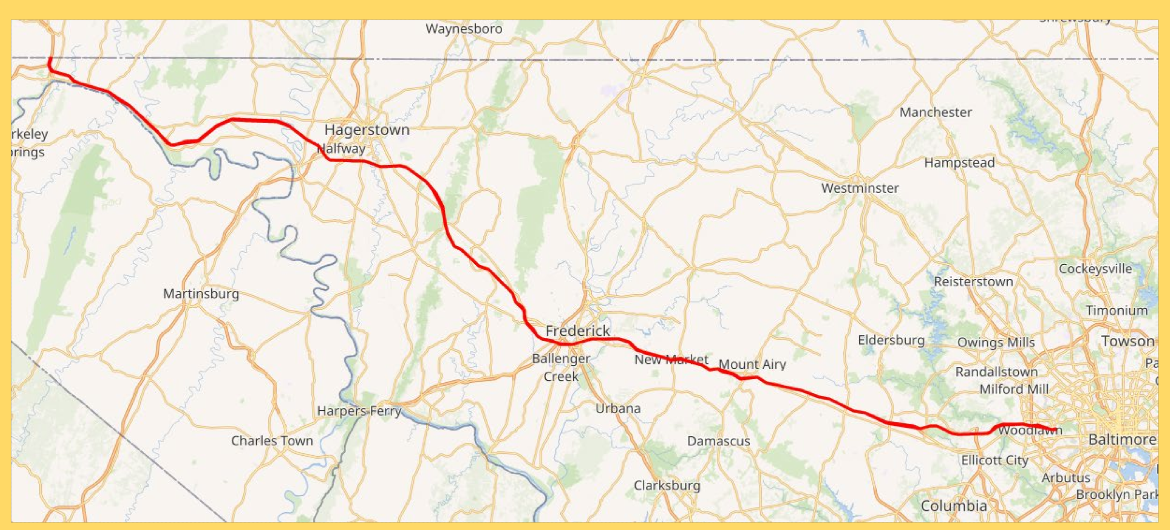
Transferability Effectiveness Test

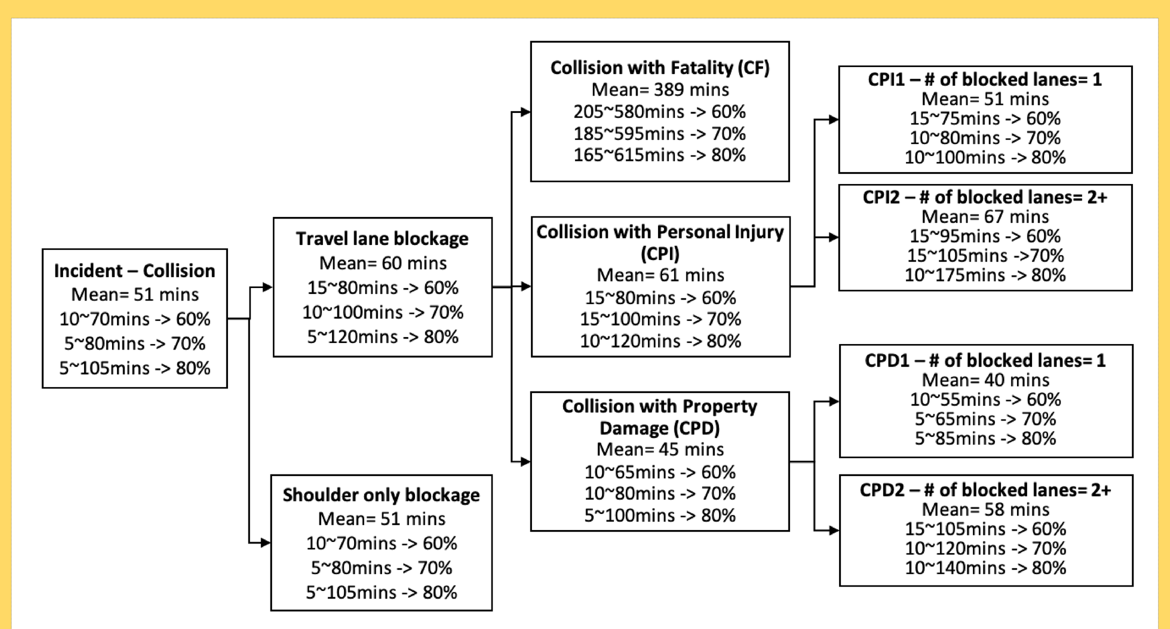
Two MOEs, 1) *confidence level* and 2) *support level*, are used to determine the transferable rules among the rules from the Rule Box



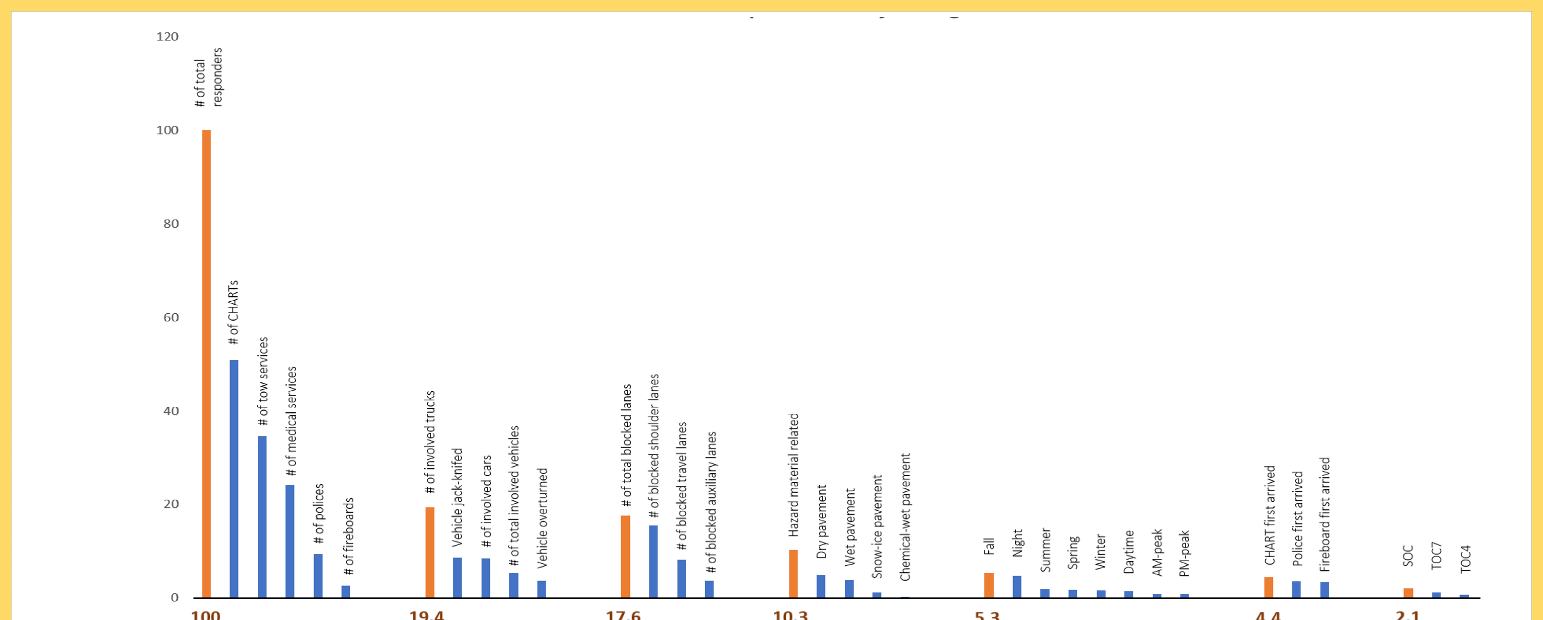
Case Study

I-70 in Maryland was selected for the case study. The 2016-2018 incident records from the CHART II Database were for model calibration, and those from 2019 served for performance evaluation





Transferability Analysis

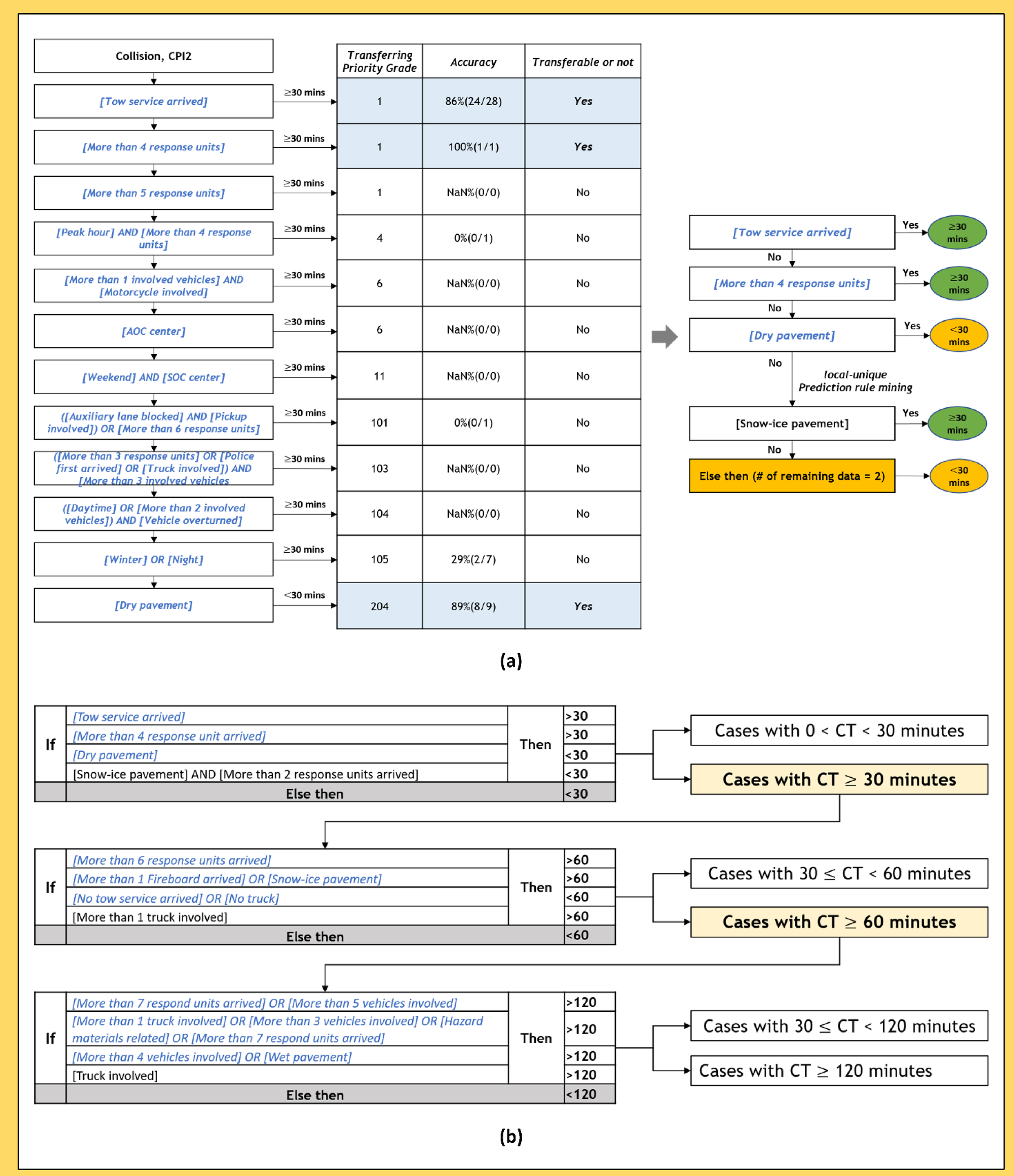


Category	# of responders	Vehicle status	Lane blockage	Pavement conditions	Time	First arrived responder	Operation center
Transferability ranking-I	1	2	3	4	5	6	7

	# of Responders	First arrived responder	Vehicle status	Pavement conditions	Lane blockage	Operation center	Time
Coverage (# of cases)	2979/0.665[a]	247/0.074	1478/0.640	1220/0.203	343/0.154	596/0.079	684/0.268
Accuracy (mean)	83%/0.377	75%/0.341	85%/0.383	89%/0.404	88%/0.398	82%/0.370	82%/0.371
Proportion of conjunctive rules	0.59/0.331	0.80/0.449	0.64/0.357	0.39/0.246	0.68/0.380	0.69/0.386	0.81/0.457
$E-val$	1.000	0.411	0.642	1.000	0.567	0.521	0.444
Rank	1	7	3	1	4	5	6

	# of Responders	First arrived responder	Vehicle status	Pavement conditions	Lane blockage	Operation center	Time
Frequency	134	15	129	41	31	16	54
Optimal transferability ranking	1	7	2	4	3	6	5

An example of an Application



Model Evaluation

Evaluated by groups of incident records						
	CPI1	CPI2	CPD1	CPD2	CF	Overall
Training set (2016-2018)	87.80% (36/41)	85.37% (35/41)	86.17% (81/94)	87.50% (35/40)	100% (6/6)	86.94% (193/222)
Test set (2019)	100.00% (10/10)	68.75% (11/16)	78.26% (18/23)	90.00% (9/10)	100% (1/1)	81.67% (49/60)

Conclusions

- To circumvent the demanding developing efforts and the need for an extensive dataset for calibration of an IDPM's prediction rules, this study has proposed an innovative KTA model that allows the construction of a new system to take advantage of existing IDPMs' embedded rules with an automated process
- The effectiveness of the proposed model has been evaluated with the incident data from I-70 in Maryland, revealing that the performance of the IDPM for I-70, with 67% of transferred rules, can yield the prediction accuracy comparable to existing IDPMs that demand much more development resources
- Future research along this line includes: 1) extending the KTA model's application to major signalized arterials mostly with a small size of incident records, and 2) constructing a supplemental module to enhance the efficiency and robustness of the rule-based IDPMs.