



KEPUTUSAN DEKAN FAKULTAS TEKNOLOGI INFORMASI UNIVERSITAS BUDI LUHUR

NOMOR : K/UBL/FTI/000/002/09/25

TENTANG:

PENUGASAN KEGIATAN TRI DHARMA & PENUNJANG BAGI DOSEN FAKULTAS TEKNOLOGI INFORMASI UNIVERSITAS BUDI LUHUR SEMESTER GASAL TAHUN AKADEMIK 2025/2026

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Ditetapkan di : Jakarta

Tanggal : 02 September 2025

Dekan Fakultas Teknologi Informasi



Dr. Ir. Achmad Solichin, S.Kom., M.T.I



**LAMPIRAN KEPUTUSAN DEKAN FAKULTAS TEKNOLOGI INFORMASI
UNIVERSITAS BUDI LUHUR**

NOMOR : K/UBL/FTI/000/002/09/25

**TENTANG:
PENUGASAN KEGIATAN TRI DHARMA & PENUNJANG BAGI DOSEN
FAKULTAS TEKNOLOGI INFORMASI UNIVERSITAS BUDI LUHUR
SEMESTER GASAL TAHUN AKADEMIK 2025/2026**

No	NUPTK	Nama	Program Studi
1	6356750651130093	ABDUL MUIS SOBRI	Teknik Informatika (S1)
2	5934758659137112	ACHMAD ADITYA ASHADUL USHUD	Teknik Informatika (S1)
3	4437767668130323	ACHMAD ARDIANSYAH	Teknik Informatika (S1)
4	7937760661130282	ACHMAD SOLICHIN	Ilmu Komputer (S3)
5	5454763664230162	AGNES ARYASANTI	Sistem Informasi (S1)
6	1947743644130112	AGUNG PRIHARTONO	Sistem Informasi (S1)
7	4652761662130272	AGUNG SAPUTRA	Teknik Informatika (S1)
8	8141761662130183	AGUS UMAR HAMDANI	Sistem Informasi (S1)
9	2636769670130302	AHMAD PUDOLI	Teknik Informatika (S1)
10	3955753654130082	AKHMAD UNGGUL PRIANTORO	Ilmu Komputer (S2)
11	1653757658130122	ANDY RIO HANDOKO	Teknik Informatika (S1)
12	1646766667130292	ANGGA KUSUMA NUGRAHA	Teknik Informatika (S1)
13	8947761662230262	ANITA DIANA	Sistem Informasi (S1)
14	0544751652130173	ANTON SATRIA PRABUWONO	Ilmu Komputer (S2)
15	4535772673130233	ANWAR RIFA'I	Teknik Informatika (S1)
16	5060770671130293	AQMAL MAULANA	Teknik Informatika (S1)
17	6647764665131142	ARI SAPUTRO	Manajemen Informatika (D3)
18	5239757658130173	ARIEF WIBOWO	Ilmu Komputer (S3)
19	0543756657130133	ARIF BRAMANTORO	Ilmu Komputer (S2)
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26	9551750651130082	BRURI TRYA SARTANA	Sistem Informasi (S1)
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28	3251756657130123	DARMAWAN BAGINDA NAPITUPULU	Ilmu Komputer (S2)
29	5560751652130083	DENI MAHDIANA	Sistem Informasi (S1)



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31	3535770671130233	DEVIT SETIONO	Sistem Informasi (S1)
32	1542762663230293	DEWI KUSUMANINGSIH	Sistem Informasi (S1)
33	4454761662130162	DIAN ANUBHAKTI	Sistem Informasi (S1)
34	7637741642130122	DJATI KUSDIARTO	Sistem Informasi (S1)
35	2243767668130313	DOLLY VIRGIAN SHAKA YUDHA SAKTI	Teknik Informatika (S1)
36	4556758659231082	DWI PEBRIANTI	Ilmu Komputer (S2)
37	9560763664230232	DWI PUSPITA ANGGRAENI	Teknik Informatika (S1)
38	2155762663131103	FERDIANSYAH	Komputerisasi Akuntansi (D3)
39	3453751652130073	FX BIMA CAHYA PUTRA	Sistem Informasi (S1)
40	2538753654130102	GANDUNG TRIYONO	Sistem Informasi (S1)
41	9043744645130083	GATOT PURWANTO	Sistem Komputer (S1)
42	4751753654230082	GRACE GATA	Komputerisasi Akuntansi (D3)
43	0537746647130122	GUNAWAN PRIA UTAMA	Teknik Informatika (S1)
44	0740763664130282	HADIDTYO WISNU WARDANI	Teknik Informatika (S1)
45	5846747648130102	HARI SOETANTO	Ilmu Komputer (S3)
46	9838763664130292	HARIS MUNANDAR	Teknik Informatika (S1)
47	8857759660131082	HENDRI IRAWAN	Sistem Informasi (S1)
48	0652765666130282	HILLMAN AKHYAR DAMANIK	Teknik Informatika (S1)
49	4735758659130162	HUMISAR HASUGIAN	Sistem Informasi (S1)
50	0434764665230262	IKA SUSANTI	Teknik Informatika (S1)
51	8949771672130282	IKHSAN RAHDIANA	Teknik Informatika (S1)
52	3941771672130302	IMAN PERMANA	Sistem Komputer (S1)
53	7437754655230112	IMELDA	Teknik Informatika (S1)
54	7746771672230342	INDAH PUSPASARI HANDAYANI	Sistem Informasi (S1)
55	2654764665130222	INDRA	Teknik Informatika (S1)
56	7454765666130203	INDRA HERTANTO	Teknik Informatika (S1)
57	9950765666130302	INDRA NUGRAHA ABDULLAH	Ilmu Komputer (S2)
58	0537752653130122	IRAWAN	Sistem Komputer (S1)
59	6435760661230183	ITA NOVITA	Sistem Informasi (S1)
60	7734743644130092	JAN EVERHARD RIWUROHI	Ilmu Komputer (S3)
61	1944770671130422	JEREMY JONATHAN	Sistem Informasi (S1)
62	9456761662130143	JOKO CHRISTIAN	Manajemen Informatika (D3)
63	2935754655130132	JOKO SUTRISNO	Sistem Informasi (S1)
64	2851769670130282	KUKUH HARSANTO	Sistem Informasi (S1)
65	9849754655130112	LAUW LI HIN	Sistem Informasi (S1)



No	NUPTK	Nama	Program Studi
66	5460755656230082	LESTARI MARGATAMA	Teknik Informatika (S1)
67	6849759660131132	LIS SURYADI	Komputerisasi Akuntansi (D3)
68	3457756657130123	LUHUR BAYUAJI	Ilmu Komputer (S2)
69	1654747648130072	MARDI HARDJIANTO	Ilmu Komputer (S2)
70	8639765666237002	MARINI	Sistem Informasi (S1)
71	5540767668230303	MEPA KURNIASIH	Teknik Informatika (S1)
72	4562753654230103	MERRY ANGGRAENI	Teknik Informatika (S1)
73	2453748649130073	MOHAMMAD ANIF	Teknik Informatika (S1)
74	9248752653130093	MOHAMMAD SYAFRULLAH	Ilmu Komputer (S2)
75	0643760661230242	MOTIKA DIAN ANGGRAENI	Sistem Informasi (S1)
76	2961757659200032	MUFTI	Teknik Informatika (S1)
77	0333764665130313	MUHAMAD SALMAN ALFARISI	Manajemen Informatika (D3)
78	1961760661130172	MUHAMMAD AINUR RONY	Teknik Informatika (S1)
79	7050757658237093	NAWINDAH	Sistem Informasi (S1)
80	6050754655230123	NIDYA KUSUMAWARDHANY	Sistem Informasi (S1)
81	3547763664230252	NOFIYANI	Sistem Informasi (S1)
82	5037758659230233	NONI JULIASARI	Sistem Informasi (S1)
83	4847756657231432	NURWATI	Sistem Informasi (S1)
84	1834757658230202	PAINEM	Sistem Informasi (S1)
85	2543764665230232	PEPI PERMATASARI	Sistem Informasi (S1)
86	4554760661230252	PIPIN FARIDA ARIYANI	Teknik Informatika (S1)
87	4151756657130113	PURWANTO	Teknik Informatika (S1)
88	8540769670230272	PUTRI HAYATI	Teknik Informatika (S1)
89	2362766667131233	RAHMAT OKTAVIAN	Teknik Informatika (S1)
90	5947771672230352	RATNA KUSUMAWARDANI	Sistem Informasi (S1)
91	3537759660230223	RATNA UJIAN DARI	Sistem Informasi (S1)
92	4656758659230152	RETNO WULANDARI	Sistem Informasi (S1)
93	0949761662230182	REVA RAGAM SANTIKA	Teknik Informatika (S1)
94	0443759660230253	RIRI IRAWATI	Sistem Komputer (S1)
95	1660744645230082	RIRIT ROESWIDIAH	Teknik Informatika (S1)
96	1745767668230302	RISKIANA WULAN	Teknik Informatika (S1)
97	2959764665237002	RIZKA TIAHARYADINI	Teknik Informatika (S1)
98	4456766667130233	RIZKY PRADANA	Sistem Informasi (S1)
99	4943758659130162	RIZKY TAHARA SHITA	Teknik Informatika (S1)
100	6235757658230143	RUSDAH	Ilmu Komputer (S2)
101	6249760661230213	SAFITRI JUANITA	Sistem Informasi (S1)



No	NUPTK	Nama	Program Studi
102	4554753654230092	SAFRINA AMINI	Teknik Informatika (S1)
103	3444749650130102	SAMIDI	Ilmu Komputer (S2)
104	4261760661230183	SAMSINAR	Sistem Informasi (S1)
105	9937760661130262	SEJATI WALUYO	Teknik Informatika (S1)
106	0157741642130083	SETYAWAN WIDYARTO	Ilmu Komputer (S2)
107	0241752653237043	SRI MULYATI	Sistem Informasi (S1)
108	3542749650230153	SRI WAHYUNINGSIH	Sistem Informasi (S1)
109	0246748649131143	SUBANDI	Teknik Informatika (S1)
110	7944752653130152	SUBANDI	Teknik Informatika (S1)
111	5937767668130372	SYAMSUDIN ZUBAIR	Teknik Informatika (S1)
112	4549736637130032	TATANG WIRAWAN WISNUADJI	Sistem Komputer (S1)
113	5539750651131093	TEJA ENDRA ENG TJU	Sistem Informasi (S1)
114	7552757658230133	TITIN FATIMAH	Sistem Informasi (S1)
115	7449765666230222	TRI IKA JAYA KUSUMAWATI	Sistem Informasi (S1)
116	6447751652130113	UTOMO BUDIYANTO	Teknik Informatika (S1)
117	4639763664130282	WAHYU PRAMUSINTO	Manajemen Informatika (D3)
118	9252739640130053	WENDI USINO	Ilmu Komputer (S3)
119	4749764665137022	WINDARTO	Teknik Informatika (S1)
120	7854758659230162	WINDHY WIDHYANTY	Teknik Informatika (S1)
121	9758748649230072	WIWIN WINDIHASTUTY	Sistem Informasi (S1)
122	2257766667230243	WULANDARI	Sistem Informasi (S1)
123	7863755656130092	YANI PRABOWO	Sistem Komputer (S1)
124	3948765666230332	YESI PUSPITA DEWI	Sistem Informasi (S1)
125	0448750651130092	YUDI SANTOSO	Sistem Informasi (S1)
126	6945763664130252	YUDI WIHARTO	Teknik Informatika (S1)
127	4057766667230303	YULIANAWATI	Sistem Informasi (S1)
128	7061753654230083	YULIAZMI	Sistem Informasi (S1)
129	6952768669130332	ZAQI KURNIAWAN	Teknik Informatika (S1)

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Serious game intelligent transportation system based on internet of things

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ABSTRACT

This research examines the implementation of the preference ranking organization method for enrichment evaluation (PROMETHEE) approach for multi-criteria decision-making in a character recommendation system for serious games. The method calculates character skill values across multiple criteria and generates rankings of the best characters according to game environment conditions derived from closed-circuit television (CCTV)-based traffic detection. Image processing algorithms were applied to classify congestion levels into quiet, moderate, and busy categories, which directly influence gameplay modes. Experimental results show that PROMETHEE rankings vary across maps (e.g., A6 ranked highest in quiet mode, while B2 dominated in busy mode), demonstrating the system's contextual adaptability. Usability testing with 50 participants yielded an average system usability scale (SUS) score of 78.9, while expert evaluation using game design factor questionnaire (GDFQ) produced a mean of 4.19/5, both indicating high acceptance and positive user experience. These findings confirm that PROMETHEE is effective in generating context-aware recommendations, providing both strategic depth and engagement. The study concludes that integrating traffic data into serious game design can enrich intelligent transportation systems (ITS) education and awareness, with future improvements possible through real-time player feedback adaptation and machine learning-based traffic prediction.

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1. INTRODUCTION

Intelligent transportation systems (ITS) are considered increasingly mature not only in terms of automation [1] but also saving on the basis of ACPs [2] and real-time data processing [3], [4]. Each process presents technologies that improve transportation performance [5], [6] such as geographic information systems (GIS) [7]. Methodologies and tools are very valuable [8]. Technologies such as machine learning and big data help traffic flow [9], while closed-circuit television (CCTV) is now often used to monitor road

conditions [10], detect accidents [11], determine incident locations [12], optimize traffic lights [13], and simulate autonomous vehicles [14]. Although many studies have examined CCTV-based control and learning, the application of these ideas to educational or gaming contexts is still rare [15], [16]. There is one metaverse simulation based on ITS [17] but none is based on a serious game yet. While serious games have a significant impact, for example, in preventing cyberbullying [18], fruit education [19], and educational environments [20] that clearly focus on one thing: learning goals and skill improvement [21], it is important to provide elements that are both entertaining and challenging for users, such as endless runners [22]. Endless runners have been applied in previous research, such as studying medical [23] and medical plants [24]. The combination of games and internet of things (IoT) [25] was one of the starting points of research that initially used webcams for emotion recognition [26] and parking detection [27]. This study combines all of the above with the addition of the PROMOTHEE method, following the principles of computerized adaptive practice [28] for player leveling and difficulty. Similar to VR-PEER [29], traffic data is taken from a real-world system and classified congestion levels, then tested on 50 participants.

2. METHOD

Since 2015, there has been an increase in research on the integration of serious games (SG) with the IoT. By 2024, the combination of IoT and ITS will also be very complex and increasingly numerous. A summary of the key findings from these studies is shown in Table 1.

Table 1. Related work

Paper	Serious game	IoT	Intelligent transport system simulation	Simulation	Optimization
Pokrić <i>et al.</i> [28]	√	√			
Garcia <i>et al.</i> [29]	√	√			
Tangworakitthaworn <i>et al.</i> [30]	√	√			
Sumit and Chhillar [31]		√		√	
Cui and Lei [32]		√		√	
Zamani and Kalbasi [33]		√		√	
Gupta <i>et al.</i> [34]		√		√	
Alsbou <i>et al.</i> [35]		√		√	
Hiroi <i>et al.</i> [36]		√		√	
Rajput and Jain [37]			√		√
Proposed	√	√	√	√	√

Multi-criteria decision-making (MCDM) methods are applied in the context of ITS and IoT, but for serious games it is still not massive. For example, there is the potential of preference ranking organization method for enrichment evaluation (PROMETHEE) for ITS optimization compared to analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS). This topic does not yet have quantitative validation [32]. Then there is the IoT-based DEMO EDICT simulation in network evaluation [38]. Urban traffic systems also have not combined the use of MCDM methods, thus limiting their connection to serious games and real-world adaptive gameplay [37].

A comprehensive study also shows that AHP is more widely used in the integration of MCDM methods than PROMETHEE, confirming the scarcity of research exploring the potential of PROMETHEE in game-based adaptive systems [39]. The PROMETHEE method was introduced to assess the level of trust of participants in an urban planning game, demonstrating the potential of PROMETHEE in assessing aspects of player behavior [40]. On the other hand, the comparison of PROMETHEE with AHP and TOPSIS in determining the location of solar PV farms with the highest score in PROMETHEE (0.92 compared to 0.85 in AHP and 0.78 in TOPSIS), confirming the superiority of this method in the ITS context even though it has not been directly applied to serious games [41].

2.1. Serious game

Serious games are mental learning through computers based on certain rules, utilizing entertainment for training [42], simulation [43], teaching [44] and learning process [45], health world simulation [46], policy simulation [47], tourism destinations [48], communication simulation [49], and environment [50], [51]. Serious games has been applied in various fields to facilitate the teaching and learning process and improve learning concentration [52]. The main benefits of serious games include providing learning motivation [53], improve logical reasoning, and enhance the interactive side [54]. Endless runner is recognized as one of the perfect genres in game because this game does not contain violence, racism, or pornography [55]. The game has many obstacles that train the player's concentration [56]. The goal of this player is to get as many scores as possible [57]. The endless runner game can be played by all ages because the concept is easy to understand [58]. This type of game uses 2D or 3D character models that can be played on mobile phones [42] and computers [59].

2.2. PROMETHEE formulation

To rank the alternatives (characters) based on multiple criteria, the PROMETHEE is applied [60].

- Preference function: for each pair of alternatives, a and b with criterion k , the preference function is:

$$P_k(a, b) = F_k(d_k(a, b)), \quad d_k(a, b) = f_k(a) - f_k(b) \quad (1)$$

where $f_k(a)$ is the evaluation of alternative a under criterion k .

- Preference index: the global preference index of alternative a over b is defined as:

$$\pi(a, b) = \sum_{k=1}^n w_k \cdot P_k(a, b), \quad \sum_{k=1}^n w_k = 1 \quad (2)$$

where w_k is the weight of criterion k .

- Preference function: for each pair of alternatives, a and b with criterion k , the preference function is:

$$\phi^+(a) = \frac{1}{m-1} \sum_{b \in A, b \neq a} \pi(a, b), \quad \phi^-(a) = \frac{1}{m-1} \sum_{b \in A, b \neq a} \pi(b, a) \quad (3)$$

- Preference function: for each pair of alternatives, a and b with criterion k , the preference function is:

$$\phi(a) = \phi^+(a) - \phi^-(a) \quad (4)$$

The alternatives are then ranked according to $\pi(a)$, where higher values indicate better ranking.

2.3. Intelligent transportation system

ITS encompass a wide range of applications, journey time planning [61], traffic flow prediction [62], vehicle safety system [63], and route optimization [64]. ITS deployment is expected to solve mobility management challenges [31], traditional and electric vehicles, as well as effective and low-cost [37]. ITS enhancements contribute to improving prediction accuracy, effectively switch lanes, and mitigating the propagation of traffic congestion [65].

2.4. Internet of things

The latest innovation [66] that can be used in research and it connect between sensor-based objects to the Internet, we call as IoT. IoT consists of communication, data, computation, and dynamic sensing of objects because they are sensor-based [67]. Researchers predict that in the future when IoT is deployed in large numbers, it will generate dynamic sensor-based data every second [68]. The information [69] or data obtained is then analyzed and reported in a format that is easy to visualize [70] so that it is easy to understand.

2.5. System design

The design of serious game-Intelligent transportation systems (SG-ITS) consists of five main parts which are CCTV placement, traffic jam, vehicle counting, serious game information and SG-ITS. The connection/hierarchy diagram shown in Figure 1. The finite state machine (FSM) design of SG-ITS, shown in Figure 2, illustrates the game flow and alternative selections determined using the PROMETHEE method, which evaluates six criteria based on player achievements. Players navigate from the main menu to map and character selection, where the system either recommends a character via PROMETHEE or proceeds directly to gameplay based on the player's manual choice. In the development process, data preparation serves as a primary phase in building the alternative selection system of SG-ITS. In this stage, the data required are alternatives and criteria. This data is related to and crucial for determining the final calculation results.

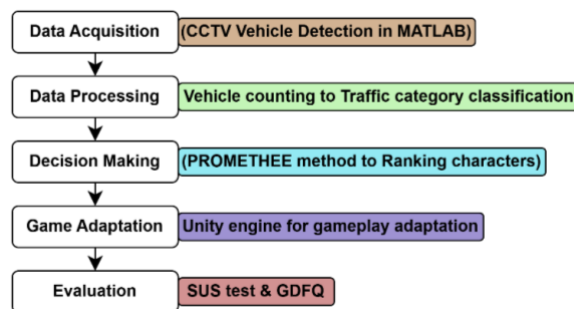


Figure 1. Hierarchy diagram of the analysis

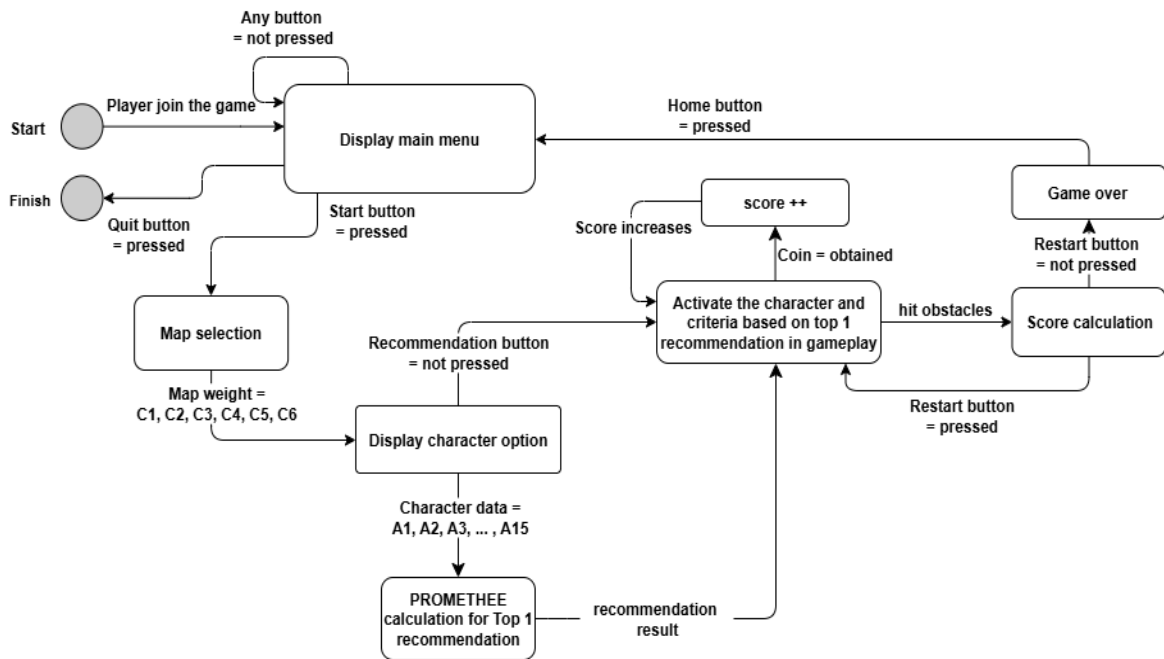


Figure 2. FSM system in unity

2.5.1. Alternative

Alternative data contains the characters players will use in this SG-ITS game. It generally includes several options with a set of values that support players in winning the game. Each character will provide a unique experience and can help players overcome higher difficulty levels. This data contains characters with prices summarized in the Table 2.

Table 2. Alternative

Alternative	Price
A1	50
...	...
A14	700
A15	800

2.5.2. Criteria

The criteria used to evaluate characters in the game are listed in Table 3, with each criterion weighted differently based on traffic conditions. On maps with calm traffic, it's recommended to look for characters with high quickness and coin surge, as this will make collecting coins more efficient. On moderate maps, it's recommended to look for characters with high coin puller, as this will generate more coins but with slightly heavier traffic. On the most difficult maps, namely busy, it's crucial to have barrier protection, as it will protect players from high-impact vehicle impacts.

Table 3. Criteria

Criteria	Means	Map		
		Quiet	Moderate	Busy
C1	Quickness	0.23	0.10	0.12
C2	Coin puller	0.14	0.36	0.12
C3	Jumping	0.14	0.25	0.16
C4	Barrier	0.16	0.08	0.33
C5	Coin surge	0.19	0.10	0.10
C6	Sprint	0.15	0.12	0.18

2.6. Game design

2.6.1. Storyline

The SG-ITS game features a storyline where a character must run endlessly through a congested urban environment. Traffic conditions are crucial because they affect how well the player controls their character and interacts with coins and other items on the road. Initially, CCTV cameras capture images of traffic jams on a particular road, which are then processed using Python. Traffic jams in the game dynamically adapt based on the scans. Players with high scores will increase the intensity of the challenge and the level of traffic jams, and vice versa.

2.6.2. Storyboard

The storyboard provides support to the implementation as it illustrates the concept and storyline of the game from start to finish in Table 4. Table 4 shows that there are six types of scene menus: menu, instruction, map, character, charr recomm, and gameplay. Each menu has its own function. For example, in the map scene, players can choose a map to determine where they will play. In the character scene, this page displays a list of playable characters, and players can choose the role they want to play. The gameplay scene is the main scene to be played.

Table 4. Storyboard

Scene	Explanation
Menu	Upon first entering the game, players are presented with the main menu consists of start, high score, credit and quit.
Instruction	Players can find out how to control the character and use features such as magnets to get more coins in instruction page.
Map	Players can choose map to determine where the player will play.
Character	This page displays list of playable characters.
Char-recomm	This page will allow player to get recommendation character.
Gameplay	This is the main gameplay page.

2.7. Test plan

The SG-ITS system was tested to evaluate the use of the PROMETHEE method for character recommendations based on traffic conditions derived from CCTV image analysis. CCTV functions as a contextual visual element rather than performing real-time recording, while image processing in Python classifies traffic levels into busy, moderate, and quiet categories. Game experts use ratings to determine whether a character meets the criteria for recommended gameplay. Meanwhile, general users provide feedback through a Google Forms-based survey. The combined results from system testing, expert evaluation, and user feedback were analyzed to determine the effectiveness of the PROMETHEE integration and guide further development of SG-ITS.

3. RESULTS AND DISCUSSION

3.1. System testing results

The calculations are taken from CCTV scans and map classification. Then, the PROMETHEE calculation implementation is placed in a recommendation button in the character selection menu. The results are integrated into the unity environment so that they can be played by players.

3.1.1. Image processing algorithm testing

Test data derived from CCTV video using Python will obtain vehicle density classification with light, medium, and busy traffic categories. Detection accuracy is done by comparing the number of detected vehicles with the number of ground truth vehicles, and the results are stored in the database. The number of vehicles can be seen in representing the traffic category (Figure 3). Detection performance is also evaluated using a confusion matrix with TP=3, FP=2, FN=2, and TN=0, resulting in precision=0.60, recall=0.60, and F1-score=0.60. With these results, it can be expected that an algorithm can identify vehicles correctly but there is still a slight overestimation or underestimation that slightly affects the classification accuracy. Even so, the performance is still acceptable.

3.1.2. PROMETHEE method implementation testing

The PROMETHEE method testing is calculated from all characters, with character rankings and net flow values according to traffic conditions. Table 5 specifically presents the character skill value dataset. Table 6 shows the weighted criteria processed through the PROMETHEE formulation.

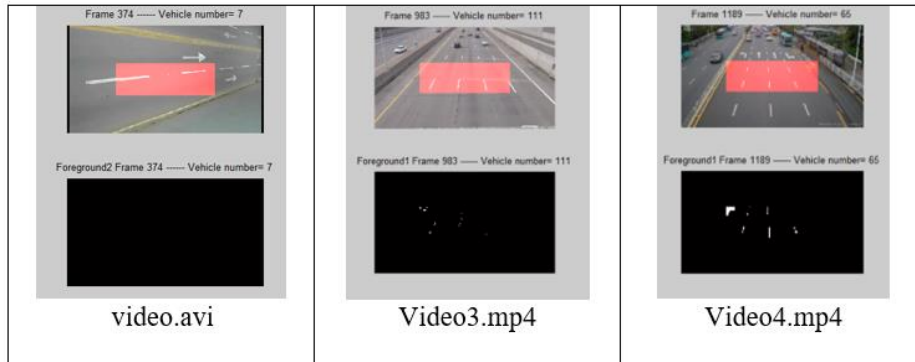


Figure 3. CCTV video

Table 5. Method testing

Criteria	Alternative														
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
C1	2	1.5	2	2	1.5	2	2	3	2	2	2	2	2	2	2
C2	3	1	2	2	3	2	2	2	2.5	2	4	3	3	4	5
C3	1	4	2	3	1	0.5	0.5	2	2.5	3.5	2	3	4	3	5
C4	3	2	1	1	2	0	0	3.5	2	2	4	2	2	2	4
C5	0	1	3	2	1	5	5	1	3.5	3.5	1	4	3	2	3
C6	3	2	2	2	3	1.5	1.5	3.5	2	2	4	3	3	3.5	5

Table 6 presents the resulting rankings, where higher net flow values indicate superior characters. In the 90-coin scenario, the process limits the choices to six feasible characters (A1–A6), which are then ranked using PROMETHEE to identify the best choice for each traffic condition. The results indicate that each alternative exhibits distinct strengths under different traffic conditions: A2 performs best in busy scenarios, while A4 maintains consistent stability across all conditions. In contrast, A1 and A5 perform weaker under quiet and moderate traffic, and A6 excels only in low-traffic situations. Overall, A4 and A2 are the most adaptive options, effectively matching varying congestion levels. The ranking distribution clearly separates high and low performing alternatives, providing useful insight for recommending characters based on available resources (player coins) and simulated traffic conditions.

Table 6. PROMETHEE net flow ranking results for character under different traffic conditions

Alternative	Result		
	Quiet	Moderate	Busy
A1	-0.38	-0.32	0.31
A2	0.06	0.16	0.53
A3	0.22	0.12	-0.13
A4	0.26	0.67	0.15
A5	-0.51	-0.38	-0.25
A6	0.35	-0.25	-0.61

Table 7 shows a significant difference in scores between players who followed the recommendations and those who didn't after two minutes of gameplay. In this case, player 1 chose alternative 1 on a quiet map, even though the system had recommended alternative 6. The result was poor character performance and a lower score. This gap is due to A6 offering a value of 5 and A1 lacking a coin boost.

Table 7. Comparison of player scores with and without PROMETHEE

Map	Recommended character	Player	Score with PROMETHEE	Score without PROMETHEE
Quiet	A6	P1	120	75
		P2	115	80
		P3	118	70
Moderate	A4	P1	140	95
		P2	138	100
		P3	142	90
Busy	A2	P1	160	110
		P2	155	105
		P3	158	100

3.2. Expert testing results

System testing involved expert respondents with professional backgrounds in game development and design. Evaluation was conducted using the game design factor questionnaire (GDFQ) (Table 8), which assesses eight key dimensions: game goals, game mechanism, interaction, freedom, sensation, game value, challenge, and flow. Each factor comprises one to four specific assessment items [71]. The answer frequency of eight key dimensions shown in Figure 4, as an example, for freedom, all of the respondent agrees, for interaction, about 45% respondents agree and about 65% disagree. Expert evaluations yielded an overall average score of 4.23/5. The game's mechanics received the highest rating (4.5) for its consistency with the chosen genre. The sensation aspect achieved a rating of 4.4 for its engaging visual interface. However, options for improving player control are still provided. These results indicate that SG-ITS meets the main standards in game structure and requires slight improvements in flexible player control.

Table 8. Game design factor questionnaire

No.	Question
1	Game goals
	- This game features well-defined tasks and stages
	- I know my objective in the game
	- I prefer to achieve and get best result in game
2	Game mechanism
	- The gameplay is accordance with the genre carried
	- The rules of the game are easy to understand
	- I like the gameplay in the game
3	Interaction
	- Interaction in playing the game is fun. Game play and controls are clear and easy to understand
	- In-game help and advice features are clear and easy to understand
	- Interaction in game play is fun
4	Freedom
	- Game characters can be easily controlled by players
5	Sensation
	- The colors and layout of the interface caught my eye
	- The icons and functions are clear and intuitive
	- The graphics and sound in the game are abundant
6	Game value
	- I want to get the highest score
	- SG-ITS content becomes interesting when added to the game.
7	Challenge
	- I feel challenged to complete the game
	- I can win the game easily
	- I want to play the advanced version of the game

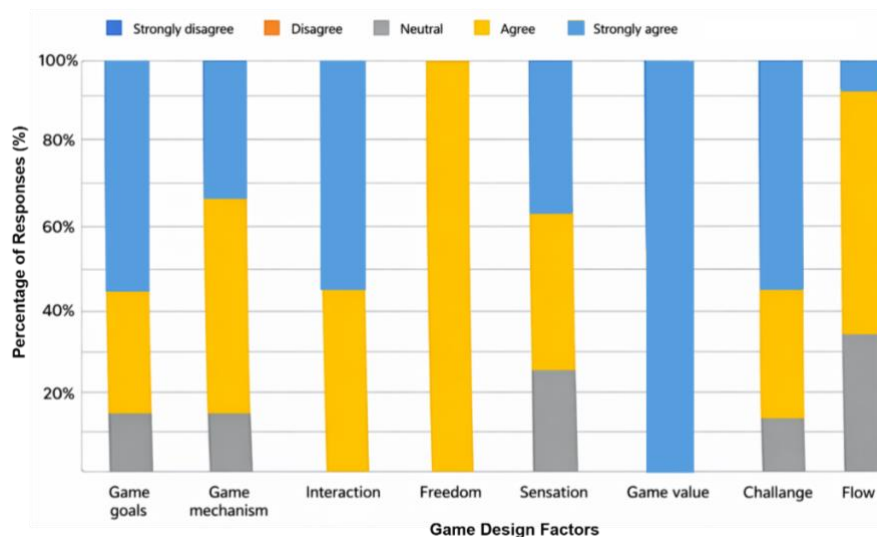


Figure 4. Test results by game experts

For the GDFQ, all expert observations (10 experts×22 items=220 ratings) as the sample. An alternative would be to test the average per expert (n =10). However, treating each item rating as an observation is often applied when the goal is to test whether the overall mean rating is significantly higher

than the neutral value, shown in Table 9. Compare $t_{calculated} = 29.99$ with $t_{critical} \approx 1.645$. Since $t_{calculated} \gg t_{critical}$, we reject H_0 at $\alpha = 0.05$. The mean GDFQ rating (4.19) is statistically far higher than neutral benchmark of 3 ($p \ll 0.001$). This indicates that experts evaluated game design factors very positively.

3.3. Usability testing

Usability testing was conducted with 50 players to measure ease of use, player satisfaction, and overall usability of the SG-ITS prototype. The system usability scale (SUS) was employed with a 1–5 Likert scale. Each of the ten questions listed in Table 10. Based on Table 10, the SG-ITS prototype achieved an average SUS score of 78.95, which is categorized as good usability (70–80) and approaching very good (>80). This indicates that most players found the game easy to operate and enjoyable. Positive items scored above 4.5, reflecting strong user engagement, while negative items scored below 2.0, indicating minimal operational difficulty as illustrated in Figure 5.

Table 9. One-sample t-test GDFQ

Item	Value
Data	
Number of respondents: n	220
Sample mean: \bar{X}	4.1909
Sample standard deviation: s	0.5890
Benchmark (null hypothesis): μ_0	3
Significance level: α	0.05
Hypotheses	
$H_0: \mu$	3
$H_A: \mu >$	3
Degrees of freedom	$df = n - 1 = 220 - 1 = 219$
Critical value	$t_{0.05,219} \approx 1.645$
Computation	$t = \frac{\bar{X} - \mu_0}{s/\sqrt{n}} = \frac{4.1909 - 3}{0.5890/\sqrt{220}} = \frac{1.1909}{0.0397} \approx 29.99$

Table 10. SUS questions

No	Question
1	I am interested in playing game again
2	I found it is quite complicated to use the game
3	The game feels user-friendly and easy to operate
4	I needed help from another person or technician while playing
5	The features in the game work as expected
6	I found some aspects of the game inconsistent
7	I believe others can easily figure out how to play the game
8	The game felt confusing to me
9	I had no difficulty using the game
10	It took me some time to adapt before I fully understood how to use the game.

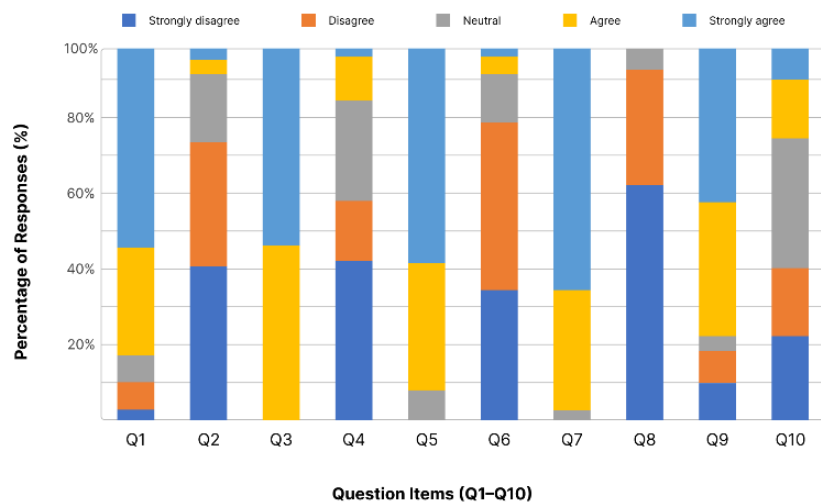


Figure 5. Usability testing results

To validate the SUS statistically, a one-sided (right-tailed) test was conducted. The hypothesis under examination was whether the sample mean score is greater than the benchmark. Based on the test data in Table 11. Decision rule compares: $t_{\text{calculated}} = 6.52$ with $t_{\text{critical}} = 1.677$. Since $t_{\text{calculated}} > t_{\text{critical}}$, we reject H_0 pada $\alpha = 0.05$. Conclusion: there is strong statistical evidence that the mean SUS score is greater than 68 ($p < 0.05$). In other words, the system's usability is significantly above the "acceptable" benchmark.

Table 11. One-sample t-test SUS

Item	Value
Data	
Number of respondents: n	50
Sample mean: X	78.95
Sample standard deviation: s	11.8783
Benchmark (null hypothesis): μ_0	68
Significance level: α	0.05
Hypotheses	
$H_0: \mu$	68
$H_A: \mu >$	68
Degrees of freedom	$df = n - 1 = 50 - 1 = 49$
Critical value	$t_{0.05,49} \approx 1.677$
Computation	$t = \frac{X - \mu_0}{s/\sqrt{n}} = \frac{78.95 - 68}{11.8783/\sqrt{50}} = \frac{10.95}{1.679} \approx 6.52$

3.4. Comparison with existing works

In python-based vehicle detection, the detected accuracy is 84.5% across three traffic density levels, with an average processing time of about one second per frame. However, this result is still lower than the YOLOv4-DeepSORT model with 87.98% which detects 13 types of vehicles [72]. Prioritizing processing speed and smooth game integration are the main objectives in this study. Meanwhile, the YOLO-OpenCV real-time detection model approach can support dynamic game difficulty adaptation [73]. The adaptation responds in about one second and is comparable to flow-state-based [74] and fuzzy logic-based [75] difficulty adjustment approaches. Its main strength lies in leveraging real-world traffic data, making in-game challenges contextually relevant. However, system performance depends on CCTV quality and may experience latency due to network disruptions or detection degradation.

3.5. Discussion

The results of image processing show that the system is able to detect vehicles and classify traffic with fairly good accuracy. with a low number of false positives and false negatives, this shows that the algorithm also remains stable in various conditions. The PROMETHEE-based character recommendation system produces a balanced ranking and is consistent with the game's objectives. Based on expert feedback assessments of 4.23 out of 5, and the SUS test, the system obtained an average score of 78.96. These results indicate that the SG-ITS game has good usability, effective functions, and is positively received by users.

4. CONCLUSION AND FUTURE WORK

This study has successfully integrated an MCDM-based recommendation system, combined with CCTV image detection algorithms, and transformed real-world traffic data into an open-world game mechanic. The PROMETHEE integration method for character recommendation based on traffic conditions demonstrates a strong alignment between gameplay and adaptive strategies. Expert and user evaluations through SUS testing also confirm that the system is well-designed and engaging. Therefore, further innovations to the system could be made to enhance the realism and adaptability of the environment. Machine learning-based traffic predictions can also be added, adjusting the difficulty based on player feedback from biometric data. This is optimized for real-time performance through edge and parallel computing. Further developments could include the introduction of transformer-based multiclass vehicles and predictive modeling to anticipate traffic trends, enabling a more intelligent and immersive serious game experience.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

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O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

This study does not involve individual personal data or identifiable human subjects. Therefore, informed consent was not required.

DATA AVAILABILITY

The data that support the findings of this study were obtained from the first author. These data were used with permission and are not publicly available due to licensing restrictions. Requests for access may be directed to the corresponding author, [FN], subject to approval from the original authors.

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