ตัวแบบเซลลูลาร์ออโตมาตาสำหรับจำลองการจราจรบนท้องถนน กรณีศึกษา : ใจกลางเมือง จังหวัดชัยภูมิ

CELLULAR AUTOMATA MODEL FOR ROAD TRAFFIC SIMULATION CASE STUDY : CHAIYAPHUM CITY.

Sangsan Kratoorerk[1] and Group of Researchers

บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์ เพื่อเก็บสถิติการจราจรบนท้องถนนในใจกลางเมือง จังหวัดชัยภูมิ ด้วยตัวแบบเซลลูลาร์ออโตมาตา โดยประยุกต์ใช้กับการไหลของยานพาหนะประเภทรถยนต์ ตัวแปรที่ใช้ศึกษาวิจัยได้จากการเก็บรวบรวมข้อมูลภาคสนามจากกล้องวงจรปิดของหน่วยงานเทศบาลเมืองชัยภูมิ ข้อมูลได้มาประกอบด้วย จำนวนยานพาหนะประเภทรถยนต์ที่อยู่บนท้องถนน เพื่อนำมาพิจารณาหาความสัมพันธ์ในสมการและอัลกอริทึม ซึ่งทำให้เห็นถึงความหนาแน่นในช่วงเวลาเร่งด่วน กลุ่มประชากรที่ได้มาจากการเก็บข้อมูลภาคสนามในช่วงเวลาเร่งด่วน 3 ช่วงเวลาที่สร้างผลกระทบทำให้มีการจราจรมีความแน่นหนาและสามารถทำให้เกิดภาวการณ์ติดขัดของการจราจร จำนวนเวลาที่เก็บแต่ละช่วงเป็นแค่ช่วงเวลาละ 10 นาที ก็สามารถทำให้เห็นสภาพการจราจรที่ติดขัดได้ ผลจากวิจัยที่ได้จากการสร้างตัวแบบจำลองและได้นำข้อมูลมาพิจารณาผ่านสมการและทฤษฎีของการจราจรเซลลูลาร์ออโตมาตา พบว่าความเร็วโดยเฉลี่ยของยานพาหนะประเภทรถยนต์ด้านระยะทางต่อเวลาคือ $\approx$33 กม./10นาที. จากจำนวนยานพาหนะประเภทรถยนต์ทั้งหมดคือ 88 คัน ดังนั้นความเร็วที่เหมาะสมสำหรับการเคลื่อนที่คือ $\approx$48 กม./10นาที. พื้นที่ว่างจากการใช้กฎ CA-184 พื้นที่ว่างของเซลล์คือ 96 (Gaps) และพบว่าการเคลื่อนที่ของยานพาหนะที่ไม่เหมาะสมทำให้เกิดการติดขัดจำนวน 88 คัน การวิจัยประเภทตัวแบบเซลลูลาร์ออโตมาตาสามารถสร้างตัวแบบในกรณีศึกษาได้หลากหลาย ด้วยการปรับเปลี่ยนกรณีศึกษาไม่มีสิ้นสุด และยังมีทฤษฎีเซลลูลาร์ออโตมาตาการจราจรหลากหลายประเภท รวมทั้งสายทางการแพทย์ และวิเคราะห์ด้านการศึกษา เป็นต้น

คำสำคัญ : ความหนาแน่น, การจราจร, ช่วงเวลาเร่งด่วน, ความเร็ว, ช่วงระยะห่าง, ทางแยก, แล็ทติท, ปริมาณงานต่อหน่วยเวลา, ทาแยกร่วม, สภาวการณ์ของระบบที่มีการเปลี่ยนแปลงทำให้เกิดช่วงเวลา, กฎการส่งผ่านระบบใช้สำหรับการอธิบายถึงความสัมพันธ์ระหว่างสถานะเซลล์ของตัวปริมาณงานต่อหน่วยเวลาแบบเซลลูลาร์ออโตมาตามช่วงเวลาใดเวลาหนึ่ง

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Abstract

This research is aimed to statistically collect the current road traffic in the hub of Muang Chaiyaphum by using cellular the automata model applied on such traffic. The variables for this research are the data collected in the field by using the official closed-circuit television (CCTV) of Muang Chaiyaphum Municipality for finding out the relations of Formula Algorithm of the traffic during rush hour times. The field data collected during three different periods of rush hours, at ten minutes per period, having created traffic congestion. The result of the research which was received by using the model and the data which was considered through the formula and the cellular automata traffic theory found that the average speed of vehicles (automobiles) was ≈33 km./10 mins. from the whole quantity of 88 automobiles cars. Therefore, the appropriate driving speed is ≈48 km./ 10 mins. The empty area from using CA-184 Rule. The empty area of cell was 96 (Gaps) and it was found out that the movement of in appropriate vehicles led to traffic congestion were 88 cars. The Cellular Automata Model Research type can be made in many case studies by changing the case studies. In addition, there are many types of cellular automata traffic models including medical and educational analysis.

Keyword *:* Density, Traffic, Rush Hour, Speed, Space Gaps, Intersection, Lattice, Throughputs, Ramp, Time Step, Transition Rule.

1. INTRODUCTION

Nowadays vehicles on the road have been increasing and the road traffic has been dense. It has created traffic congestion in the community, especially in educational, government, and private areas during the rush hours. The aforementioned traffic problem has created slow movement to the vehicles. Such a problem has brought about the effects to society, economy and transportation. Moreover, the people's quality of life has been getting worse.

Chaiyaphum Province has been changed in economy and transportation. The quantity of vehicles, outside and inside the city, has increased very fast. The lane changing of vehicles, the traffic lights at the crossroads, the space between vehicles, and the speed movements of vehicles have effects and created traffic congestions. The authorities in charge of the road traffic have not successfully solved this problem. So far, the peoples in Chaiyaphum city have still encountered the problem of the road traffic.

The Cellular Automata Model for Road Traffic Simulation, Case Study : Chaiyaphum City has the fundamental theory of cellular automata model. The changing of vehicle status based on Von Neuman (Sven, M., & Bart De, M. 2005) and Moore Neighborhoods (Sven, M., & Bart De, M. 2005) would make the TCA model consisted of the vehicle state changing. The Wolfram's Rule 184 (Stephen, W. 2012) Rule184. Retrieved September 4, 2012) has helped in seeing state of vehicles for binary data processing, Time Steps Measurement Period for microscopic data processing (Sven, M., & Bart De, M. 2005). Therefore, definition of time measurement is Number of Lane, Number of Vehicle, Space Gaps and Headway. It has been used with changing lane condition no matter about time and distance. Because of the road traffic problem in Chaiyaphum city, researchers were interested in studying and experimenting with the cellular automata theory. The result of the study was aimed to distribute to authorities involved with the road traffic. It will also serve as a subject of Computation Theory, Department of Computer Sciences, Faculty of Arts and Sciences, Chaiyaphum Rajabhat University.

2. OBJECTIVES

1) To study and test the Cellular Automata Model, Case Study : Road Traffic Real Situation.

2) To study quality of life and social problem regarding road traffic of the people in Chaiyaphum Province.

3) To study and take this matter into learning lesson on Computation Theory.

4) To collect statistical counting number of vehicles running on the road in Chaiyaphum Province.

3. SCOPE OF THE RESEARCH

1) Place of model setting: Center of Chaiyaphum City.

2) Rush Hours: Morning from 07. 00 a.m. to 07. 10 a.m.; noon from 12.00 a.m. to 12.10 p.m. and afternoon from 16.00 to 16.10 p.m.

3) Populations and Samples of the Model (private car) must be 4 meters long.

4) Research data collected in the field was received under Scope and Limitation of the Research.

5) Vehicles, automobile type, definition as of Automobile Act 2522

4. RESEARCH INSTRUMENTS

1) Through closed circuit cameras, the automobile count at each Red Traffic Light where there have been moving in and out of cars in microscopic view.

Figure 1. CCTV: interjection at Engineer Division.

Figure 2. CCTV: interjection at Rong Lueai.

Figure 3. CCTV: interjection at Satri-Chaiyaphum School.

Figure 4. CCTV: interjection at Lertnimit Hotel T-Junction.

Figure 5. CCTV: interjection at Non Hai Intersection.

2) Google Earth Pro Program was used to measure each road in Chaiyaphum City, in microscopic type.

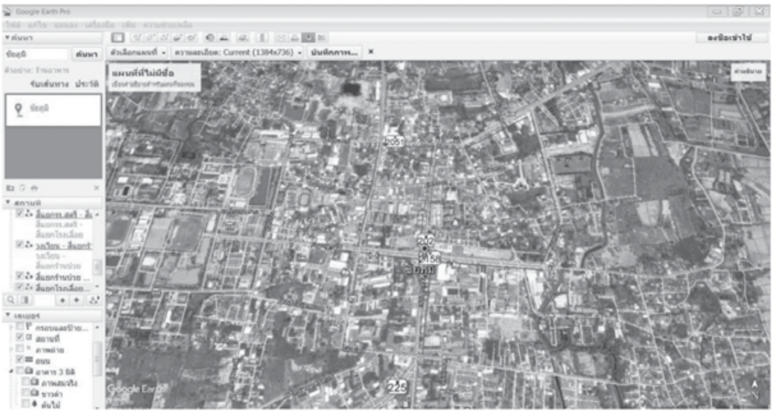


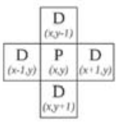
Figure 6. Macroscopic view by Google Earth Pro Program. (Sven, M., & Bart De, M. 2005B)

5. METHODOLOGY

5.1 Elementary Cellular Automata (TCA) (Sven, M., & Bart De, M. 2005A)

Cellular Automata are a model combined with various fields such as Computer Theory, Physics, and Biology. The related field is Computation Theory of The Computer Sciences Program. The small model composed of different geometric figures depending on its application. As for this research, the definition of cellular is a cell with geometric shape. The automata are a moving system which are clearly separate from each other in space and time. It has been done on the same lattice or array of n dimension and have the specific interaction. The cellular automata model has often been used with the complicated system. Therefore, it has been used to solve problems consisting of various physical areas with complicated the relations. It also indicated the changing complicated behavior. It could explain about physical system and its procedure well. The model related to this research is Euclidean Lattice Topologies of the 2-D Cellular Automata Model.

The Cell's Neighborhoods



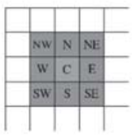


Figure 7. Von Neumann Neighborhood **Figure 8.** Moore Neighborhood (Sven, M., & Bart De, M. 2005B)

The moving directions of Von Neumann and Moore, in comparison, were different in moving limitations. Moore could move to many more directions than Von Neumann.

5.2 Space Measurement of Cellular Automata Model (Sven, M., & Bart De, M. 2005A)

The Macroscopic and Microscopic level is geological structure for analysis state of traffic and density of vehicles. As for this Research, three structures are available.

Figure 9. Space Measurement of Cellular Automata Model.

5.3 CA-184 Rule (Stephen, W. 2012 Rule184. Retrieved September 4, 2012)

The CA-184 Rule is composed of binary number as the deterministic model resulted in 256 rules as absolute values. It was seen that the state of changing cells was significant of Wolfram's 184 Rule. However, this rule was basic for Cellular Automata Model. Other models could take this rule as reference for computation of time values.

5.3.1 Formula (Santen, L. 1999)

1*27+0*26+1*25+1*24+1*23+0*22+0*21+0*20 = 128+0+32+16+8+0+0+0 =184

$$\left|\sum \Sigma^{N}\right| = 2^{2^{3}} = 256$$

$$\Delta V = \frac{\Delta X}{\Delta T}$$

ΔV = Speed m/s

ΔX = Distance

ΔT = Time Step

current pattern	111	110	101	100	011	010	001	000
new state for center cell	1	0	1	1	1	0	0	0

Table 1. Example of CA-184 Rule

6. DATA COLLECTION

This research is a study of Cellular Automata Model for the road traffic by using map model and data collection of the road traffic through the cellular automata moving rule. Details of research methodology:

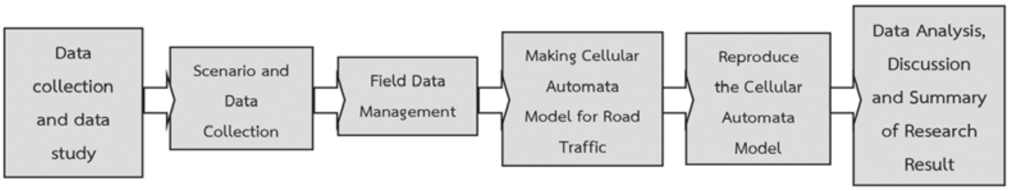


Figure 10. Research Methodology

7. DATA ANALYSIS

Only automobile type vehicles, the distance measurement was made from the junction with traffic light to the intersection, considering directions vehicles enter into the city and leave the city. The measurement was done in the morning, at noon time, and in the afternoon.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Quantity of Vehicle (Leaving the City)
8.00 น. - 8.10 a.m.	Car	1 unit = 1 car	1 unit = 1 car
12.30 น. - 12.40 p.m.	Car	1 unit = 1 car	1 unit = 1 car
16.30 น. - 16.40 p.m.	Car	1 unit = 1 car	1 unit = 1 car

Table 2. Data Analysis consisted of the data from Rong-Lueai Intersection, Satri-Chaiyaphum School Intersection, Municipal Engineer Division Intersection, Lertnimit Hotel T-Junction and Non Hai Intersection

8. RESULTS

The Research "Cellular Automata Model, Case Study : Chaiyaphum City" was composed of field data collection, automobile count, and distance measurement of each route. Therefore, the statistical number of automobile coming in and going out of Chaiyaphum City was made available. The speed of each automobile was records. The Cellular Automata Model could tell the appropriate gaps and the speed of each automobile.

1. Result of Data Collection

1. Rong Lueai Intersection			
Period of Time	Vehicle Type	Entering the City	Leaving the City
8.00 a.m. - 8.10 a.m.	Car	33	5
12.30 p.m. - 12.40 p.m.	Car	19	25
16.30 p.m. - 16.40 p.m.	Car	45	51
2. Satri Chaiyaphum School Intersection			
8.00 a.m. - 8.10 a.m.	Car	71	5
12.30 p.m. - 12.40 p.m.	Car	32	17
16.30 p.m. - 16.40 p.m.	Car	65	49
3. Municipal Engineer Division Intersection			
8.00 a.m. - 8.10 a.m.	Car	22	12
12.30 p.m. - 12.40 p.m.	Car	18	9
16.30 p.m. - 16.40 p.m.	Car	51	38
4. Lertnimit Hotel T-Junction			
8.00 a.m. - 8.10 a.m.	Car	64	5
12.30 p.m. - 12.40 p.m.	Car	27	33
16.30 p.m. - 16.40 p.m.	Car	68	65
5. Non Hai Intersection			
8.00 a.m. - 8.10 a.m.	Car	64	5
12.30 p.m. - 12.40 p.m.	Car	27	33
16.30 p.m. - 16.40 p.m.	Car	68	65

Table 3. Data Set of Intersection.

1. Simulation of Cellular Automata (TCA)

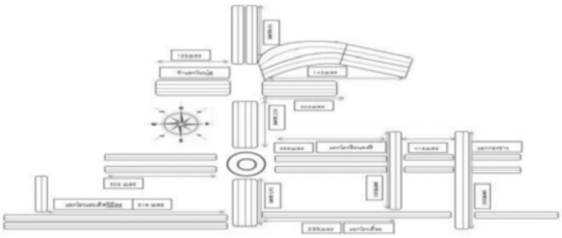


Figure 11. Picture showing lanes of Cellular Automata in the center of Chaiyaphum City. (Alexandre, D., & Bastien C. 2003)

Figure 12. Picture of specific cells of Cellular Automata in the center of Chaiyaphum City e.g. Lertnimit Hotel Intersection. (Sven, M, & Bart De, M. 2005A , T, S, & J, W. 2007 , Xingang L., & Ziyou, G., & Bin J. 2009)

8.1 DATA ANALYSIS OF EXPERIMENTAL RESEARCH (Qiang, M., & Jinxian, W. 2011 , Monica D., & Sergiu G., & Eduard F. 2002)

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	33	≈19	58	25
12.30 p.m. - 12.40 p.m.	Car	19	≈23	58	39
16.30 p.m. - 16.40 p.m.	Car	45	≈18	58	**13

Table 4. Rong Lueai Intersection – Entering the City (232 meters/4 meters = 58 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈18 and Gaps at 13 = 0. Gaps between Vehicle = 33 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Leaving the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	5	≈22	58	53
12.30 p.m. - 12.40 p.m.	Car	25	≈20	58	33
16.30 p.m. - 16.40 p.m.	Car	51	≈18	58	**7

Table 5. Rong Lueai Intersection –Leaving the city (232 meters/4 meters = 58 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈18 and Gaps at 7 = 0. Gaps between Vehicle = 51 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	65	≈20	66	**1
12.30 p.m. - 12.40 p.m.	Car	32	≈23	66	34
16.30 p.m. - 16.40 p.m.	Car	59	≈20	66	7

Table 6. Satri Chaiyaphum School Intersection : Entering the City (265 meters / 4 meters = 66 cars) Most cars were available during 8.00 – 8.10 hrs. The lowest speed could be done (q_{min}) ≈20 and Gaps at 1 = 0. Gaps between Vehicle = 65 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Leaving the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	5	≈26	66	51
12.30 p.m. - 12.40 p.m.	Car	17	≈24	66	49
16.30 p.m. - 16.40 p.m.	Car	49	≈21	66	**17

Table 7. Satri Chaiyaphum School Intersection : Leaving the City (265 meters/4 meters = 66 vehicles) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈21 and Gaps at 17 = 0. Gaps between Vehicle = 49 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	22	≈39	104	82
12.30 p.m. - 12.40 p.m.	Car	18	≈40	104	86
16.30 p.m. - 16.40 p.m.	Car	51	≈36	104	**53

Table 8. Engineer Division : Vehicles entering the City (419 meters/4meters =104 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈36 and Gaps at 53 = 0. Gaps between Vehicle = 51 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Leaving the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	12	≈40	104	92
12.30 p.m. - 12.40 p.m.	Car	9	≈40	104	95
16.30 p.m. - 16.40 p.m.	Car	38	≈38	104	**66

Table 9. Municipal Engineering Division : Vehicles leaving the City (419 meters/4meters =104 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈38 and Gaps at 66 = 0. Gaps between Vehicle = 38 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	64	≈45	129	65
12.30 p.m. - 12.40 p.m.	Car	27	≈49	129	102
16.30 p.m. - 16.40 p.m.	Car	68	≈45	129	**61

Table 10. Lertnimit Hotel T-Junction: Vehicle entering the City (519 meters/4 meters = 129 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈45 and Gaps at 61 = 0. Gaps between Vehicle = 68 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Leaving the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	5	≈50	129	124
12.30 p.m. - 12.40 p.m.	Car	33	≈48	129	96
16.30 p.m. - 16.40 p.m.	Car	65	≈45	129	**64

Table 11. Lertnimit Hotel Intersection : Vehicle leaving the City (519 meters/ 4 meters = 129 cars).Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈45 and Gaps at 64 = 0. Gaps between Vehicle = 65 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	89	≈33	105	**16
12.30 p.m. - 12.40 p.m.	Car	41	≈38	105	64
16.30 p.m. - 16.40 p.m.	Car	68	≈35	105	37

Table 12. Non Hai Intersection : vehicles entering the City (422 meters / 4 meters =105 cars) Most cars were available during 8.00 – 8.10 hrs. The lowest speed could be done (q_{min}) ≈33 and Gaps at 16 = 0. Gaps between Vehicle = 89 which Cells State = 1.

Period of Time	Type of Vehicle	Quantity of Vehicle (Entering the City)	Speed (km/10 min.)	Quantity of Vehicle/ Distance /Cells State	Gaps
8.00 a.m. - 8.10 a.m.	Car	77	≈34	105	28
12.30 p.m. - 12.40 p.m.	Car	48	≈37	105	57
16.30 p.m. - 16.40 p.m.	Car	88	≈33	105	**17

Table 13. Non Hai Intersection ; vehicle leaving the City (422 meters /4 meters = 105 cars) Most cars were available during 16.30 – 16.40 hrs. The lowest speed could be done (q_{min}) ≈33 and Gaps at 17 = 0. Gaps between Vehicle = 88 which Cells State = 1.

9. SUMMARY OF RESEARCH RESULTS AND DISCUSSION

The Cellular Automata Model for Road Traffic Simulation Case Study : Chaiyaphum City Research presented the state of the road traffic in the center of Chaiyaphum City during the rush hours with traffic congestions and high density of vehicles. The researcher is happy to present the research results and comments as follows.

According to the research result analysis, traffic controllers and vehicle drivers must consider speed and gaps of vehicles in order to get less effect of overall image. From field data collections, the researcher found out that during the period 16.30 – 16.40 hrs.,at every intersection in Chaiyaphum City, there has been traffic congestion risk.

According to the field data collection, during the period 8.00 – 8.10 hrs. Non Hai Intersection had highest density of vehicles, 89 cars during 8.00 – 8.10 hrs. The speed of vehicle was lowest at 33 km/10 min and gaps of vehicle were 16 cells state.

The movement of vehicle entering and leaving the center of Chaiyaphum City is still facing problems of traffic congestion during rush hours. The population of automobile owners has been increasing.

10. SUGGESTION

1) Suggestion for utilization of the research results. Research results can be used on road traffic in the center of Chaiyaphum City. Results of this research were given to Chaiyaphum Municipality and Police Station : Traffic Section.

2) Suggestion for Future Research: Because there was no a closed circuit camera at Chaopho Phaya Lae Monument, the field data were not collected. Moreover, supporting funds

for Research data collection were insufficient. Therefore, further financial support for the future research must be requested.

11. ACKNOWLEDMENT

The Cellular Automata Model for Road Traffic Simulation, Case Study : Chaiyaphum City, was funded by 2558 Annual Budget of Chaiyaphum Rajabhat University. The research was successfully available because of diligence and assistance of Chaiyaphum Municipality and The Institute of Research and Development.

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