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Design of an Agent Based Traffic-Information Collection System

Kenedy Aliila Greyson[1]

Abstract

Currently, traffic congestions are common events in road networks of main cities in developing countries. It has been observed that, the size of congestion increases year after year. For traffic congestion management to work efficiently, sufficiently and accurately information are needed. In this research we present an alternative method using agent technology to collect and manipulate data so as to be used in optimizing the vehicle flow within the road networks. The objective is to design an agent based system to provide sufficient and accurate information used in traffic flow management, and vehicle traffic congestion mitigation. The implementation approach is presented. The case study is a portion of the road network from the city of Dar es Salaam.

[1] Intelligent System Research Unit, Department of Electronics and Telecommunications Engineering, Dar es Salaam Institute of Technology (DIT), P.O. Box 2958, Dar es Salaam, Tanzania, e-mail: kenedy@dit.ac.tz, kenedyaliila@yahoo.com

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1 Introduction

The traffic congestion management system consists of three sections: input, processing and output. The input is responsible for data collection which is then processed so as to obtain the status of the road network. The information obtained is used in the control system. The performance of the control system depends on the availability of sufficient and accurate information of the road network system.

There are several strategies towards the traffic congestion mitigations with the aim of reducing the burden of excessive congestion throughout the urban road network of most cities of developing countries [1]. However, there is no single solution expected to solve the congestion problem in the road networks of those cities completely. For instance, it is reported in [2] that congestion in Dar es salaam, Tanzania, is always changing from bad to worse year by year. It is forecasted that, with assumption that the proposed plans to be implemented in full and in time, the vehicle traffic congestion will be substantially worse in the few years later. There are several negative impacts of traffic congestions as mentioned in [1], [2], [3] and [10]. Just to mention few, negative effects include: waste time of motorists and passengers (delay), inability to forecast travel time accurately, waste of fuel, increase in air pollution and carbon dioxide emissions, wear and tear on vehicles, and elevated crash rates.

While it is estimated that, delay or a lost time as a consequence of traffic congestion across the United States may average 20 hours per year per person, in Los Angeles, it is estimated to be approximately 10 minutes a day, or one sixth of one's average travel time [4]. In Dar es Salaam, delay average is two (2) hours daily per person, or four times one's average travel time [2]. For a total of 26 or 27 working days a month, it counts to a total of 52 hours for private cars per month

and more than 600 hours per year per person. Authors in the report [4] also comment that, a private cars waste approximately $ 3.00 in one (1) hour, in consideration of only each liters of gasoline consumed while delayed. Moreover, every hour of passenger-vehicle delay is valued at $12.85 [3] in Los Angeles. This is a justification that, national economy is affected by the terrible traffic congestion in the cities of developing countries.

It has been observed that, during rush hours at major junctions in the road networks, there are traffic police officers taking charge of controlling the traffic flow instead of traffic lights and other responsible signals. Although it is suggested in [1] that the policy to manage the roads is required in the roads administration, author in [2] implies that the congestion situation in Dar es Salaam will still be worse. This research generally, intended to optimize the traffic flow hence to minimize vehicle congestion by using agent based traffic information collection system. The principle operation is based on coordinated agents to collect and process data to be used in controlling and optimizing the vehicle traffic flow in the road network. The research report [1] shows that, if congestion is expected in the road sector, the control measures are called forth.

This paper is organized as follows: section 1 presents the introduction of the congestion status and its consequences. Section 2 gives the formulation of the problem. Section 3 gives the background theory in agent technology, and Section 4 presents the method proposed in implementation of the agent based system. The conclusion is presented in Section 5 of the report.

2 Formulation of the Problem

It has been observed that, during the traffic peak or rush hours in most cities of developing countries, traffic police officers take charge in controlling the traffic flow in major junctions and intersections instead of the available static traffic light

controls or other signaling means. This suggests that, the human intelligence is needed to improve the vehicle traffic flow instead of the static traffic light controls. However, fatigue, tiredness, unpleasant weather (sun or rain), risk on the road, and lack of the network information, affect their performance in many cases. Hence artificial intelligent systems, using agents are needed to optimize the traffic flow and minimize the vehicle traffic congestion. Therefore, this research intends to design an expert system that will be used to collect and process data in traffic congestion management system.

3 Intelligent Systems

The proposed system is expected to collect and process data by using agent sensors. The knowledge based system is used in evaluating the information; therefore, it is an artificial intelligent system. With advantage of fast computation and decision making, prone to weather, agent based traffic information collection system is expected to enhance the ability to control traffic congestion, hence better performance. In agent based traffic information collection system, agents are coordinated so as to enhance achievement of some or combination of the following: minimize traffic flow delay and unnecessary stops; minimize fuel consumption; minimize pollution emissions; maximize smooth flow within the road networks; maximize capacity and to minimize the arrival in intersections at red lights [3]. The structure of the system is as shown in Figure 1.

3.1 Agents

Agent is a piece of a computer program in a hardware that perceives and acts in an environment to achieve a particular assigned task or goal. Agent perceives the condition of the respective environment by the help of sensors. The response

or action of an agent depends on the percept from sensors. Basically, an agent is a system or subsystem. In order, to achieve the objective, the coordinated agents work as a team and communicate to form a multiagent system. Agent is characterized by the following entities: autonomous, proactive, and social.

3.2 Inference Engine and Knowledge Based Tank

In order to be an intelligence system, there must be a reasonable capability driven from the knowledge tank. The inference engine is a program that is capable of using available data or information and knowledge base in order to provide an intelligent response. Knowledge based tank contains facts, along with rules that are used by the intelligent system. In actual fact, the inference engine, analogous to the brain, and knowledge based tank define the rank of intelligence of the system. Well informed expert would provide a good solution to a problem. Similarly, enough information, facts, rules and their processing approach are expected to provide a good solution in an expert system. Therefore, agent based traffic information collection system is intended to provide information to the expert or intelligent system.

4 System Design and Implementations

This research intended to develop agent based information collection system to provide sufficient information used in optimizing the traffic flow and minimizing the vehicle congestions. The agent based traffic information collection system constitutes intelligent behavior. With the help of agents, tasks include the following processes: sensing, learning; reasoning and acting. It should be noted that in order to minimize the vehicle congestion and to avoid complexity, each junction or intersection (referred to as a *node*) is managed independently while

listening from its adjacent junctions and intersections for coordination purposes. In this system, the performance depends highly on the designed relationship between the known components (inputs) and the flexibility in their control to provide the unknown components (outputs).

4.1 Learning Process

The learning process requires that all agents receive the percepts form the environment. Sensing elements such as magnetic sensing of vehicles by loop, installed into the road surface, have been used in traffic detection for a while. However, the expense of this method to cover the city network is very high. The answers to vehicle type or even speed are not provided as well. Several literatures have proposed other sensing methods such as a video camera with a computer programs. With this approach, queue extent and speed of vehicles may be included. Being a computer program, the conditional statements, such as "if… then" in a knowledge based tank are widely used in agents learning processes. Upon its individual action, agent communicates its action and proposal to other agents so as that other agents may react on the action proposed. Inference engine combines the information communicated by individual agents, information stored in the system database (server), and knowledge based tank (brain) for the system in order to provide the response.

4.2 Agent Communication Language

The coordination of agents is based on the ability of agents to communicate. The main common languages used by agents are KQML and FIPA agent communication language (ACL). In this research, FIPA ACL communicative acts included in JADE platform are used. In order to achieve the system goal, agents

communicate by informing (inform), submitting proposal(s) (propose), accept proposal(s), (agree), calling for proposals (call for proposal), asking for action (request), etc. JADE platform provides agent communication features implemented in accordance with FIPA specifications [5].

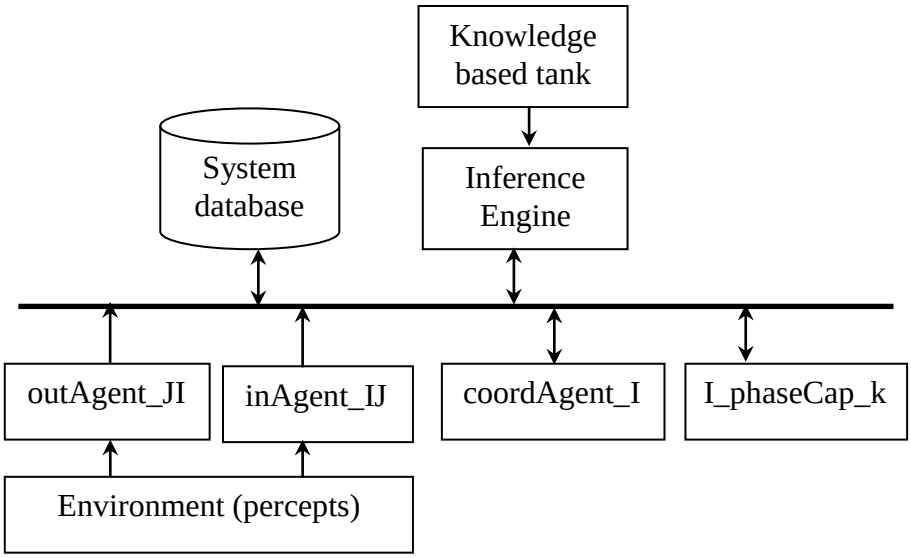

Figure 1: Basic structure of the agent based traffic information collection system

4.3 Agent Task Assignments

Each agent is assigned a particular task in their socio-community. All agents aim at the achievement of the main objective of the multiagent system. This section explains the list of task assigned to the agents. This process of assigning task to an agent is known as agent task assignment (ATA).

The window sequences (as referred in [1]) or phase sequences (as referred in [3]) shown in Figure 2 include: phase number 5 and phase number 2, phase number 1 and phase number 5, phase number 2 and phase number 6, phase number 3 and phase number 7, and phase number 4 and phase number 8.The cycle

is completed and green time starts all over again to phase 5 and phase 2, and so on. Each road sector (sometime, each lane of the road sector) is assigned an agent to obtain the road sector status (inAgent_IJ or outAgent_JI) and reports back to the intersection computation or even intersection control center. In intersection computation or intersection control center, phase capacities computation and their respective messaging process takes place by I_phaseCap_k, the computation method is clearly explained in [3].

Parameters that describe traffic stream include: volume or rate of flow, which is defined as number of vehicles that pass a given point on the roadway or a given lane or direction of a highway in a specified period of time (vehicles per hour), speed (kilometers per hour), and density, which is the number of vehicles present on a given length of roadway or lane [3]. These parameters are related by equation: Flow (veh/hr)= Density (veh/km)× Speed (km/hr). An agent is given a task to estimate the density using the relationship of the speed and flow. The density, which defines the congestion level, can be controlled if the average speed is controlled. Also, density readings distinguish between congested or uncongested conditions of the road. The control starts by determining the free-flow speed, demand flow rate and hence the average travel speed is estimated.

Although the control section is not covered in this research, we present preliminary control process, as shown in Figure 3, so as to demonstrate the application of information collected by the proposed system. If the capacity is violated in a coordinated agent environment, and if the congestion is projected, the negotiation process starts whereby the control agent proposes to other road sectors agents in the adjacent intersections, the expected adjustment that would rectify the violation. This task is accomplished by the agent coordAgent_I. Based on the priority and other road sectors status, the optimization process is established. This may be done by reducing the phase (window) timing of the less congested road sectors, if any. Readers are urged to review on control management so as to obtain the insight of the idea.

The intersection outlets are communicated to the adjacent junctions or intersections by outAgent_JI agent, which are responsible to minimize the arrival of intersections at red lights and many other optimizations. The I_phaseCap_k provides the capacity of phase k of the junction I. Other agents are as shown in Table 1. Process of forecasting the direction of the vehicle as it leaves the junction is done by the Bayesian accumulation of evidence technique. It applies the laws of probability directly to the problem. The basic theory behind Bayesian techniques can be obtained from [6] and will not be covered in this report.

The information is collected in the control centers as database which is eventually used in traffic flow control. In order to achieve the main objective, each agent must develop an effective communication within the platform and globally and build working relationship as they negotiate towards the main objective which is the laid criterion. Therefore the design starts by setting plans and goals for each agent in the system where an agent is armed with coded negotiation model for the conflict resolution via inter exchange of messages. In traffic management system, each agent is assigned an individual goal. However, in the point of decision, each goal (analogous to an issue) is prioritized. Agents may share the main goal (objective). Negotiations between the agents are provoked based on observed changes in the system. The effective way of resolving the conflict (if any) caused by the change depends on how they understand the underlying dynamics of the conflicts. The next subsections give the method used for conflict management and negotiation contention used by agents [8].

4.4 Conflict Management

Although conflict is not the interest of any social agent, it is obvious that, there will be conflicts during the process where each agent is trying to achieve its assigned objectives. The traffic flow must be maximized and all vehicles must be

able to move while maintaining the main objective of optimizing the traffic flow and minimizing the vehicle congestion. Therefore, there must be a way to solve the conflict that may arise. In this research we adapt the endless loop method, shown in Figure 4, proposed in [8] whereby, a group of agents is called during the conflict event so as to deal with unions. These agents, which act as a group manager, intervene only when the conflict is difficult to be resolved because they are costly. The process may be computation time consuming. The conflict analysis, shown in Figure 4, is the process in which the system performance is analyzed and the output determines if there is any conflict. The conflict analysis takes place to make sure that a decision would not worse the vehicle flow in other road sectors of the respective junction.

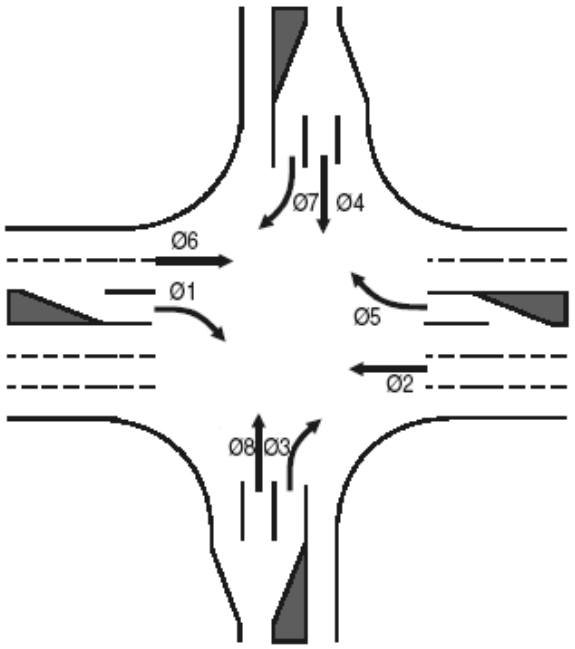

Figure 2: Example intersection layout using National Electrical Manufacturers Association (NEMA), source [3]

4.5 System Database

Database is an ordered collection of related data elements intended to meet the information needs of an organization and designed to be shared by multiple users [9], [11], and [12]. Information collected in the field, in the form of direct measurements, estimated or computed needs to be kept in agent based traffic information collection system database.

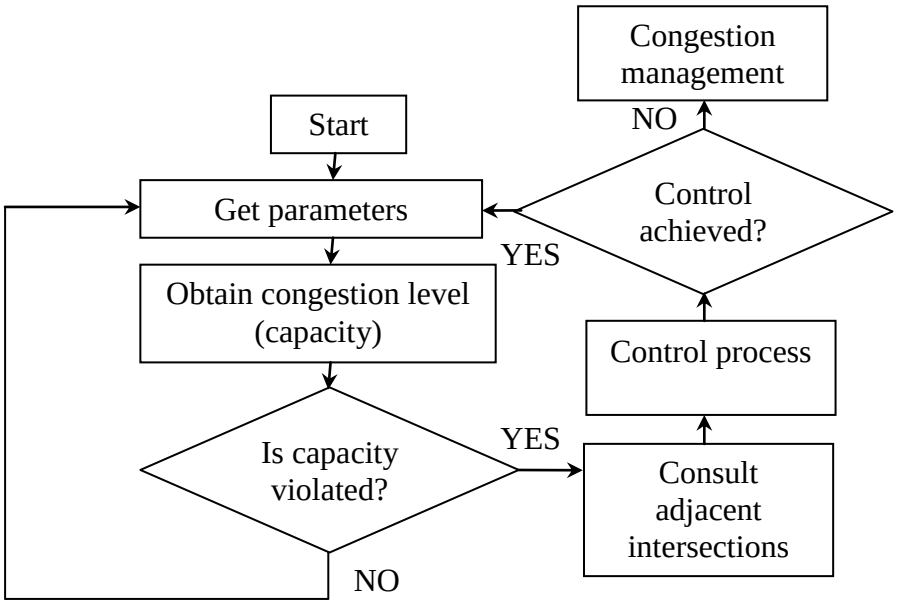

Figure 3: Intersection traffic flow preliminary control algorithm

The part of the road network, approximately 8.04 km, used for explanation is shown in Figure 5. Preliminary design of entity types for agent based traffic information collection system database in which some of the attributes will be refined into relationships is presented in Figure 6. Example of the attributes and tuples of an entity ROAD_SECTOR is as shown in Table 2. Other entities include: INTERSECTIONS, VEHICLES, etc. The diagram of INT_MOROCCO which is shown in Figure 2 is located in the network as shown in extreme left of

Figure 5. The Table 3 shows the attributes and tuples of the entity INT_MOROCCO. Other related entities may follow the similar approach. Other data includes: road sector density, traffic flow, average speed and so forth. Note also that, the estimate free-flow speed (km/ hr), speed limit and mean speed of traffic measured in the field (km/ hr), are different attributes.

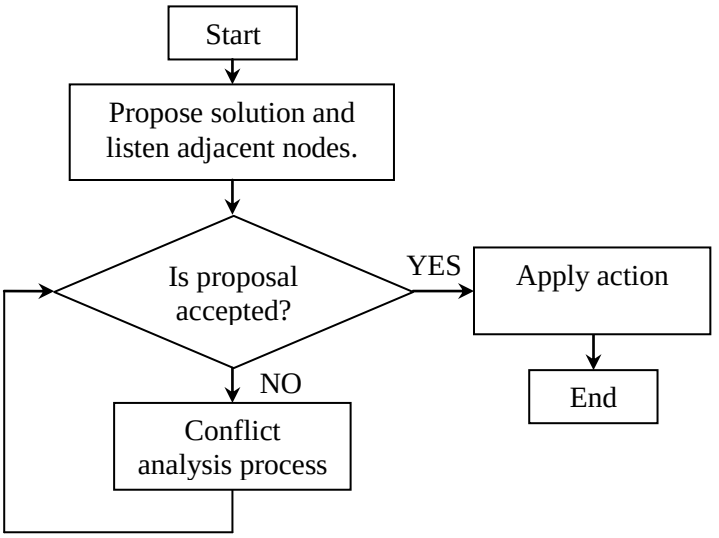

Figure 4: Conflict management system

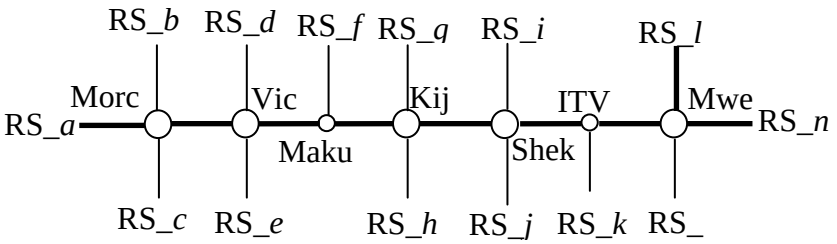

Figure 5: The part of Dar es Salaam road network

5 Conclusion

The implementation of agent based traffic information collection system in a congestion management discussed here may be affected by the policy in place. it may require that the policy is amended to suit the objective. Although general rules were used in this research, we suggest that the policy in place and regional planning agency should guide in the implementation of the agent based traffic information collection system in a respective city. The system is expected to provide information that can assist in policy amendment. Control process takes the data mined by the agent based traffic information collection system.

Table 1: Agents in agent based traffic information collection system

Agent name	Description	Action
inAgent_IJ	Provides the status of a road-sector from junction I to junction J (i.e. post msg.) Percepts: *Number of vehicles, phase capacity, origin and destination, post data.*	Informs the intersection the available load
outAgent_JI	Provides the expected status of a road-sector from junction J to junction I (i.e. post msg.) Percepts: *Number of vehicles, post data, speed, origin and destination, distance between intersections, Total green-time.*	Informs the adjacent intersection the expected coming load
I_phaseCap_k	Provides the capacity of phase k in junction I (computation and message	Computes the capacity per unit

	postings). Percepts: *Total green-time, No. of cycles per hour, saturation headway, saturation flow, size or type of vehicles, cycle length.*	time
coordAgent_I	Coordinates the agents and decision making for junction I. it also used in conflict management. Percepts: *Demands and capacities of road sectors within the junction, phase sequence, etc.*	Makes final decision and resolves conflicts

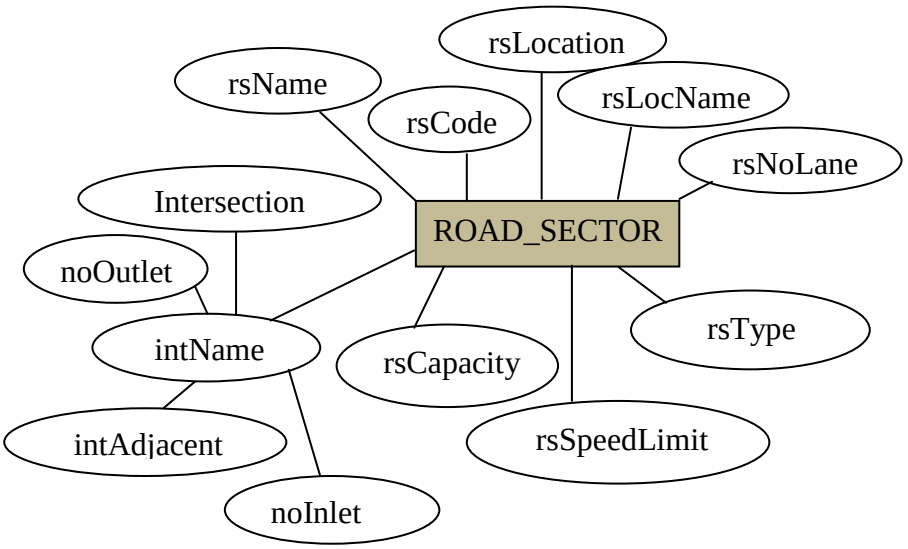

Figure 6: Preliminary design of entity types for an agent based traffic information collection system database

Table 2: The Attributes and tuples of Relation ROAD_SECTOR

	Attributes	**Tuples**		**Attributes**	**Tuples**		**Attributes**	**Tuples**
1	rsName	Mwenge	5	rsName	Maku -	9	rsName	Maku - Kijito
	rsCode	RS_01		rsCode	RS_05		rsCode	RS_40
	rsLength	1.72		rsLength	1.15		rsLength	0.82
	rsLocation	Kinondoni		rsLocation	Kinondoni		rsLocatio	Kinondoni
	rsNoLanes	2		rsNoLanes	2		rsNoLane	2
	rsType	Tarmac		rsType	Tarmac		rsType	Tarmac
	rsSpeedLim	50 (km/ hr)		rsSpeedLi	50 (km/ hr)		rsSpeedLi	50 (km/ hr)
2	rsName	ITV - Sheki	6	rsName	Victoria -	10	rsName	Kijito - Sheki
	rsCode	RS_02		rsCode	RS_06		rsCode	RS_30
	rsLength	1.91		rsLength	1.93		rsLength	1.51
	rsLocation	Kinondoni		rsLocation	Kinondoni		rsLocatio	Kinondoni
	rsNoLanes	2		rsNoLanes	2		rsNoLane	2
	rsType	Tarmac		rsType	Tarmac		rsType	Tarmac
	rsSpeedLim	50 (km/ hr)		rsSpeedLi	50 (km/ hr)		rsSpeedLi	50 (km/ hr)
3	rsName	Sheki -	7	rsName	Morocco -	11	rsName	Sheki - ITV
	rsCode	RS_03		rsCode	RS_60		rsCode	RS_20
	rsLength	1.51		rsLength	1.93		rsLength	0.91
	rsLocation	Kinondoni		rsLocation	Kinondoni		rsLocatio	Kinondoni
	rsNoLanes	2		rsNoLanes	2		rsNoLane	2
	rsType	Tarmac		rsType	Tarmac		rsType	Tarmac
	rsSpeedLim	50 (km/ hr)		rsSpeedLi	50 (km/ hr)		rsSpeedLi	50 (km/ hr)
4	rsName	Kijito -	8	rsName	Victoria -	12	rsName	ITV - Mwenge
	rsCode	RS_04		rsCode	RS_50		rsCode	RS_10
	rsLength	0.82		rsLength	1.15		rsLength	1.72
	rsLocation	Kinondoni		rsLocation	Kinondoni		rsLocatio	Kinondoni
	rsNoLanes	2		rsNoLanes	2		rsNoLane	2
	rsType	Tarmac		rsType	Tarmac		rsType	Tarmac
	rsSpeedLim	50 (km/ hr)		rsSpeedLi	50 (km/ hr)		rsSpeedLi	50 (km/ hr)

Table 3: The attributes and tuples of Relation INT_MOROCCO

phaseNo	inSector	outSector
1	RS_*a*	RS_*c*
2	RS_06	RS_*a*
3	RS_*c*	RS_60
4	RS_*b*	RS_*c*
5	RS_06	RS_*b*
6	RS_*a*	RS_06
7	RS_*b*	RS_*a*
8	RS_*c*	RS_*b*

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