# Simple Screening for High-Risk Pregnancies in Rural Areas Based on an Expert System

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***Abstract***
*The high maternal and infant mortality rates in developing countries, especially Indonesia, are quite alarming. There are many factors that cause high mortality numbers; one of them is the delay in handling cases of high-risk pregnancies. The main problem faced by developing countries is the lack of health facilities, including medical equipment and human resources. This research aims to develop a simple system that can be used to screen high-risk pregnancies. This system is based on an expert system. The Analytical Hierarchy Process (AHP) method is used in making decisions about potentially high-risk pregnancy patients. Essentially, the system can be used by anyone, anywhere, to carry out early screening of high-risk pregnancy patients, so that delays in the treatment of these patients can be resolved, because the symptoms of high-risk pregnancy are known from the beginning. Results indicate that this system shows promise for further development.*

***Keywords****: Maternal Mortality, High Risk Pregnancies, Developing Countries, Expert System, Analytical Hierarchy Process*

## 1. Introduction

During pregnancy, it is important to monitor foetal development continuously, because it has great influence on the health of both the mother and her unborn child. Generally, maternal and prenatal mortality can be used as an indicator of the nutritional and health status of the mother, the level of maternal health services and the health environment during pregnancy. Maternal Mortality Rate (MMR) is one of the indicators to ascertain the health status of women. Currently in Indonesia, the MMR is also one of the targets that were set in the Millennium Development Goals; it is included in the fifth goal of improving maternal health, in which one of the targets to be achieved by 2015 is to reduce the maternal mortality risk by three-quarters. The death of a mother is very influential on the health and lives of children left behind. If a mother dies, the children left behind are potentially three to ten times more likely to die within two years than those who still have parents [1]. Today, at least 18,000 women die every year in Indonesia as a consequence of pregnancy or childbirth. That means that every half an hour, a woman dies during pregnancy or childbirth. As a result, every year 36,000 children under five become orphans. This rate puts Indonesia in first place in ASEAN for high maternal mortality. The Household Health Survey 2001 reports that Indonesia's MMR was 396 per 100,000 live births. That number represented an increase compared with the 1995 survey results, which were 373 per 100,000 live births. The MMR in Indonesia is even worse than in Vietnam. The maternal mortality rate in that neighbouring country in 2003 was 95 per 100,000 live births. Among other ASEAN countries, Malaysia recorded 30 per 100,000 and Singapore nine per 100,000 [2].

Lack of public awareness about maternal health is the deciding factor in mortality, although many other factors must be considered in addressing this issue. Most (60% to 80%) maternal deaths are caused by bleeding during childbirth, obstructed labour, sepsis, high blood pressure in pregnancy and complications from unsafe abortion, as shown in Figure 1. The graph in Figure 1 shows the percentage distribution of causes of maternal mortality. Based on these data, there are three main factors that cause maternal mortality: bleeding, hypertension or pre-eclampsia during pregnancy, and infection [3].

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In the medical field, if a patient has a high-risk pregnancy, there are various tests or procedures in addition to routine prenatal screening tests, depending on the circumstances. A healthcare provider might recommend tests such as: (a) Specialised or targeted ultrasound**:** this type of foetal ultrasound - an imaging technique that uses high-frequency sound waves to produce images of a baby in the uterus - targets a suspected problem, such as abnormal development; (b) Amniocentesis: during this procedure, a sample of the fluid that surrounds and protects a baby during pregnancy (amniotic fluid) is withdrawn from the uterus; typically done after week 15 of pregnancy, amniocentesis can identify certain genetic conditions as well as neural tube defects - serious abnormalities of the brain or spinal cord; (c) Chorionic Villus Sampling (CVS): during this procedure, a sample of cells is removed from the placenta; typically done between weeks 10 and 12 of pregnancy, CVS can identify certain genetic conditions; (d) Cordocentesis**:** this test, also known as percutaneous umbilical blood sampling, is a highly specialised prenatal test in which a foetal blood sample is removed from the umbilical cord; typically done after week 18 of pregnancy, the test can identify chromosomal conditions, blood disorders and infections; (e) Cervical length measurement**:** a healthcare provider might use ultrasound to measure the length of a patient's cervix at prenatal appointments to determine whether she is at risk of preterm labour; (f) Lab tests: a healthcare provider might take a swab of vaginal secretions to check for foetal fibronectin, a substance that acts like a glue between the foetal sac and the lining of the uterus; the presence of foetal fibronectin might be a sign of preterm labour: (g) Biophysical profile: this prenatal test is used to check on a baby's well-being. The test combines foetal heart rate monitoring (nonstress test) and foetal ultrasound [4].

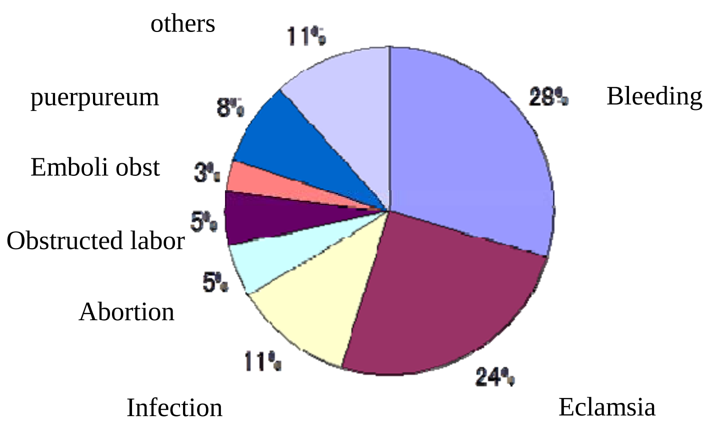


Figure1. Causes of Maternal Mortality (source: Health Department, 2011)

As regards the test procedures discussed, these are certainly not a problem if a pregnant woman lives in areas where full health services are provided, including human resources and health equipment. However, they will be a problem for pregnant women who live in rural areas with various limitations on existing health facilities. This research aims to develop a screening system for early detection of the existence of a simple high-risk pregnancy in a pregnant woman. In this research we chose to develop a screening system based on an expert system, because such a system holds certain advantages. An expert system is a computer system that is equal to the capabilities of an expert in decision making. The word 'equal' has a sense that the expert system is expected to work in all cases as well as an expert. The advantages of an expert system are: (a) expert advice is available all the time; (b) the knowledge of expert staff can be captured to some extent before they move on; (c) it can be used as a training aid to increase the expertise of staff; (d) it makes rational decisions without emotional overheads; (e) it does not get tired or overworked; (f) it is an efficient way of getting answers, as it does not involve additional help staff; and (g) a natural language interface would make the expert system more human friendly [5]. As regards the advantages of an expert system, there have been some research projects on applications in medical diagnosis. Hasan [6] carried out research on the diagnosis of human diseases using a fuzzy expert system. His research project focuses on the research and development of a web-based clinical tool designed to improve the quality of the exchange of health information between healthcare professionals and patients. Prasadl [7] carried out research on an approach to developing an expert system in medical diagnosis using a machine learning algorithm. He considered the disease asthma for diagnosis. Mitra [8] developed a fuzzy MLP model-based expert system for medical diagnosis. It is used as a connectionist expert system for diagnosing hepatobiliary disorders. It can handle uncertainty and/or imprecision in the input as well as the output. Shah [9] developed an expert system for diagnosis of skin disease using an Artificial Neural Network (ANN). Schatz [10] provided an overview of the role of intelligent tools in modern healthcare systems and reviewed current challenges in the field. Iantovics [11] developed a novel large-scale hybrid medical diagnosis system called LMDS. The LMDS system comprises physicians, medical expert system agents and medical ICMA agents. Medical ICMA agents represent a novel class of agents with the ICMA architecture. The diagnosis system can solve difficult medical diagnosis problems whose solutions must be discovered cooperatively by the members of the system. Zahrani [12] applied an expert system for prophetic medicine to breast cancer diagnosis and treatment. Haiji [13] developed an account of a rule-based expert system (RBES) for neurological disorders, i.e., Alzheimer's, Parkinson's, Huntington's disease, cerebral palsy, meningitis, epilepsy, multiple sclerosis, stroke, cluster headache, migraine and meningitis for children. More than 10 types of neurological disease can be diagnosed and treated by his system. Fuerbach [14] described a systematic method for examining public knowledge found in healthcare textbooks and practice guidelines surrounding the concept of oral feeding in premature infants in a neonatal intensive care unit. It includes the development of an instrument for extracting data from those sources to standardise definitions of terminologies.

On the other hand, our previous research concentrates on developing low-cost and easy-to-use technology to support diagnosis in the medical field based on image processing techniques [15] [16] [17] [18] [19]. Other researchers also use image processing techniques for developing computer aided diagnosis [21] [22]. However, the weaknesses in the use of image processing techniques that we have previously developed are that both hardware and software specifications used are sometimes not compatible for rural areas. In this paper, we will discuss the development of a simple screening system for high-risk pregnancies based on an expert system that is very easy to implement in rural areas. We emphasise the use of the Analytical Hierarcy Process (AHP) method for developing our system.

## 2. Research method

Basically, the diagnosis of a disease process will be divided into two conditions, namely, clinic-based and community-based. In the clinic-based condition, the diagnosis is based on laboratory tests and examinations are conducted by medical personnel directly, while in the community-based condition, the diagnosis is based on the symptoms that can be felt by the patients themselves. In this research we develop both of the conditions for screening high-risk pregnancies. The first is dedicated for use by health workers in formal health services units in order to shorten the time of the initial examination. The second condition is dedicated for groups of ordinary people widely available in developing countries such as Indonesia in order to provide first aid in initial screening of high-risk pregnancies in rural areas.

In our screening system, we use the Analytical Hierarchy Process (AHP) method to determine an alternative condition in pregnant patients.

### 2.1. Analytical Hierarchy Process (AHP)

This method is a framework for effective decision making on complex issues by simplifying and accelerating the process of decision making to resolve the problem into its parts, arranging parts or variables in a hierarchy of numerical value based on the subjective judgment of the importance of each variable and synthesise the various considerations to determine which variables have the highest priority and act to affect the outcome of the situation. The AHP method helps to solve complex problems by structuring a hierarchy of criteria and interested parties, with interesting results and considerations for developing weights or priorities. This method also combines the strength of feeling and logic concerned on various issues, and then synthesises a diverse range of considerations to be matched with the results we intuitively estimate as presented in the considerations that have been made [3] [20].

### 2.1.1. Decomposition

Decomposition is solving the problem by dividing it into a number of more specific variables. In the AHP, the decomposition process is defined as the preparation of the hierarchy of criteria, sub-criteria and alternatives related to the problem to be solved [3] as shown in Figure 2.

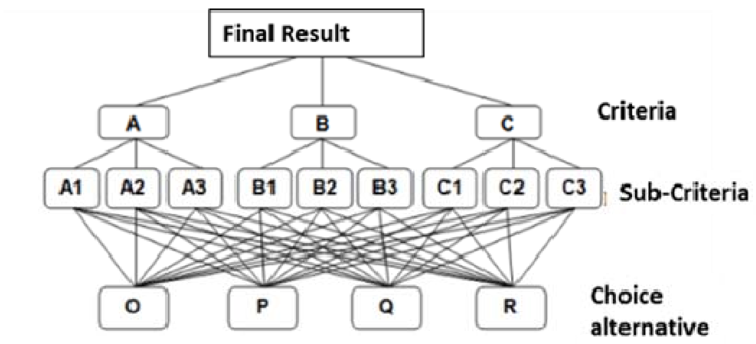


Figure 2. Hierarchical structure which is a translation problem (Source: Supriyanti R, 2013)

By using the comparative judgment principle, we determine priorities that will be used as the score for each symptom that will be used in our screening system as shown in Table 1.

Table 1. AHP pairwise comparison of assessment scales (Source: Supriyanti, 2013)

| Priority scale | Definition | Explanation |
|---|---|---|
| 1 | Equally important | Both activities have the same contribution to the object |
| 3 | Somewhat more important | Experience and assessment shows that the activity of the rather more important than the others. |
| 5 | Quite important | Experience and assessment shows that one activity is more important than the others |
| 7 | Very Important | Activity compared with activity has dominance over the other. |
| 9 | Very very important | Activity that one is really important and influential than other activities. |
| 2,4,6,8 | | The midpoint between two adjacent values decision. |
| Contrary | | When the activity of "I" has a higher value of activity "j" then "j" has the opposite value when compared with the "I". |
| Ratio | | Value / ratio is obtained directly from measurements. |

### 2.1.2. Priority synthesis

Priority synthesis is done by multiplying the local priorities and the priorities of the relevant criteria at that level and adding this to each element in the level that influenced the criteria [3].

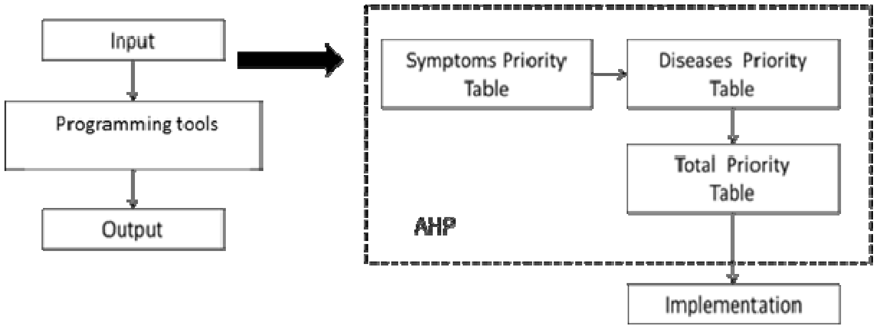


Figure 3. System Design (Source: Supriyanti R, 2013)

### 2.2. System design

According to the above explanation, we developed our screening system by implementing the Analytical Hierarchy Process. The first stage of the AHP is Structuring; structuring the flow of decision making is based on two main components; the first component is the purpose of the AHP and the variables used, while the second component comprises alternatives that can be taken to fulfil the purpose of the AHP. In phase structuring, the purpose of the AHP will be determined, as well as what variables and sub-variables are used and what alternatives are available. Structuring the AHP process is the preparation of the AHP framework consisting of the main aim, variables used as consideration and the alternatives that can be taken to meet the goals. The next phase of the AHP is Assessment, i.e. stage scoring or weighting of the variables, sub-variables and alternatives. Figure 3 shows our design system.

### 2.3. Comparison system using SuperDecision V2.2

In order to evaluate the accuracy of our screening system, we then conducted a comparison against other software and also using real field data. Superdecision is software that implements the Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP) for decision making.

### 2.4. Comparison system using real field data

In order to obtain accurate performance, in addition to comparing the results of the system which we made with the results obtained by SuperDecision V2.2, we also compared the results with results of diagnostic systems in real conditions that a doctor or midwife would operate under. In order to obtain comparative data on the real conditions, we distributed questionnaires to pregnant women patients, and asked them to reply to the same questions using our system, and then asked their doctor or midwife to diagnose the same patients. Then we compared the diagnostic results to evaluate the performance of our system.

## 3. Results and analysis

As already described in sub-section 2 above, we built the system based on two conditions, namely clinic-based and community-based. The detailed clinic-based system has already been discussed in [21], in which we achieved performance of 80%. In this paper, we will discuss the development of our previous research by developing community-based systems. One of the advantages in the use of a community-based system is that the development of a knowledge base is not as complex as the clinic-based systems [3] as shown in Table 2.

Table 2. Knowledge Base of Symptoms have Pursue

| Code | Symptom |
|---|---|
| A | Positive pregnancy test |
| B | Is age less than 18 years |
| C | Is age more than 40 years |
| D | Does feel a fewer |
| E | Does feel nauseous |
| F | Does feel dizzy |
| G | Whether abdominal pain |
| H | Whether blood pressure decreased |
| I | Whether blood pressure increased |
| J | whether rapid heartbeat and shortness of breath |
| K | Whether have diabetic history |
| L | Whether have hypertension history |

According to our previous research, we made five predictions of possible causes of maternal mortality, namely Eclampsia Hypertension, Pre-eclampsia Hypertension, Intrapartum Infection, Post Partum Bleeding, Other Disease and Normal [3]. But in real conditions, if it is applied to the ordinary community it will be quite confusing. Therefore in this research, we summarised our predictions into two conditions only: normal and high-risk pregnancy.

Referring to Table 2, we could establish a relationship between diseases during pregnancy and the symptoms that accompany them, as seen in Table 3.

Table 3. Relationships between Symptoms and Pregnancy Diseases

| | CODE | PREGNANCY DISEASES | |
|---|---|---|---|
| | | High-Risk Pregnancy | Normal |
| | A | V | V |
| S | B | V | |
| Y | C | V | |
| M | D | V | V |
| P | E | V | V |
| T | F | V | V |
| O | G | V | V |
| M | H | V | V |
| S | I | V | |
| S | J | V | |
| | K | V | V |
| | L | V | V |

After a comparison of priority symptoms to symptoms was obtained, subsequent pairwise comparisons were conducted to determine alternative priority disease to symptom criteria. Table 4 describes this priority.

Table 4. Comparison between Symptom and Symptoms Priority

| | | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H | I | J | K | L | Pv |
| 1 | A | 1.00 | 1.00 | 0.33 | 0.00 | 0.00 | 0.20 | 0.33 | 0.00 | 0.33 | 0.33 | 0.33 | 0.20 | 0.03 |
| 1 | B | 1.00 | 1.00 | 0.33 | 0.00 | 0.00 | 0.20 | 0.33 | 0.00 | 0.33 | 0.33 | 0.33 | 0.20 | 0.03 |
| 1 | C | 3.00 | 3.00 | 1.00 | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 1.00 | 0.33 | 1.00 | 0.33 | 0.08 |
| 0 | D | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0 | E | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | F | 5.00 | 5.00 | 3.00 | 0.00 | 0.00 | 1.00 | 3.00 | 0.00 | 3.00 | 3.00 | 3.00 | 1.00 | 0.24 |
| 1 | G | 3.00 | 3.00 | 1.00 | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.09 |
| 0 | H | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | I | 3.00 | 3.00 | 1.00 | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.09 |
| 1 | J | 3.00 | 3.00 | 3.00 | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.11 |
| 1 | K | 3.00 | 3.00 | 1.00 | 0.00 | 0.00 | 0.33 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.11 |
| 1 | L | 5.00 | 5.00 | 3.00 | 0.00 | 0.00 | 1.00 | 3.00 | 0.00 | 3.00 | 3.00 | 1.00 | 1.00 | 0.22 |
| 9 | Jml | 27.00 | 27.00 | 13.67 | 0.00 | 0.00 | 4.07 | 11.67 | 0.00 | 11.67 | 11.00 | 9.67 | 4.73 | 0.00 |
| | Principle Eigen Value | | | | | | | | | | | | | 9.31 |
| | Consistency Index | | | | | | | | | | | | | 0.04 |

According to Table 4, the first row and the first column are priority multiplier symptoms with other symptoms. If the cell in both the first row and the first column is blank, this indicates that the cell in inactive, while if the cell is filled in, this indicates that the cell is active. According to Table 4, it appears there are several symptoms that have a dominant priority; these are symptoms F and L, whose PV values are 0.24 and 0.22.

In order to develop a low-cost and easy-to-use screening system, we used Microsoft Excel to build our system. The advantages of using Microsoft Excel are that almost all computers, both desktops and laptops, have the Microsoft Excel application. This application is also easily operated by everyone. These advantages is enough for building a low-cost and easy-to-use screening system. Figure 4 shows an example of the display of patient data entry, while Figure 5 shows an example of the display of symptom data entry. Figure 6 shows an example of the display of diagnosis results. In order to evaluate the performance of our system, we also compare the diagnosis results with analyses using SuperDecision. First we developed a hierarchy structure using SuperDecision as shown in Figure 7. Then we developed a priority design and filled in the priority values. All processes used instructions embedded within SuperDecision

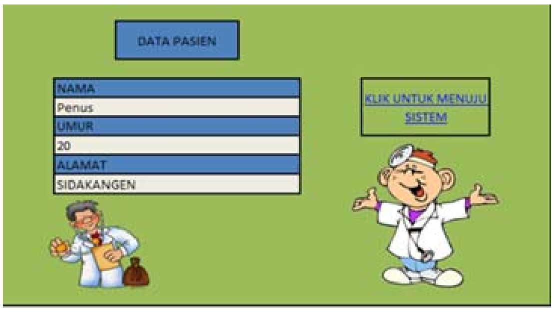


Figure 4. Display of Patient Entry Data

Figure 5. Display of Symptoms Entry Data


Figure 6. Display of Diagnosis Result

According to Figure 6, our system also provides advice on what first aid should be given by the user. For example, Hartini is a pregnancy patient. She had symptoms of high-risk pregnancy because the system showed symptoms that identify the direction of a high-risk pregnant patient at the age of 45 years.

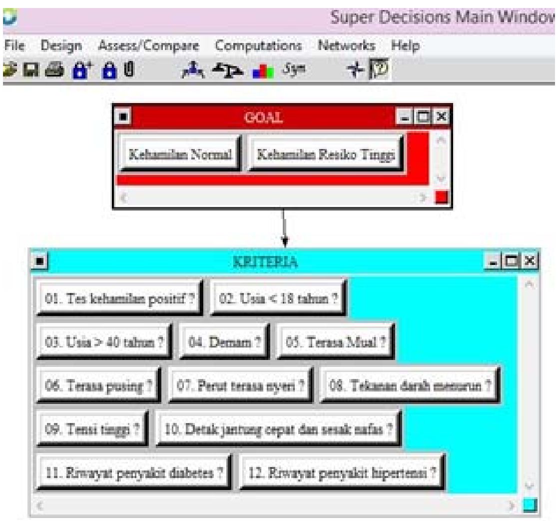


Figure 7. Hierarchy Scheme using Super Decision

According to this case, our system will provide an initial treatment by recommending her to have sufficient nutrition and rest to improve her condition. In another case, our system recommended that a patient take vitamins as early treatment. According to Figure 7, after finishing the Hierarchy Scheme using SuperDecision, we then developed rating priorities as described in Figure 8.

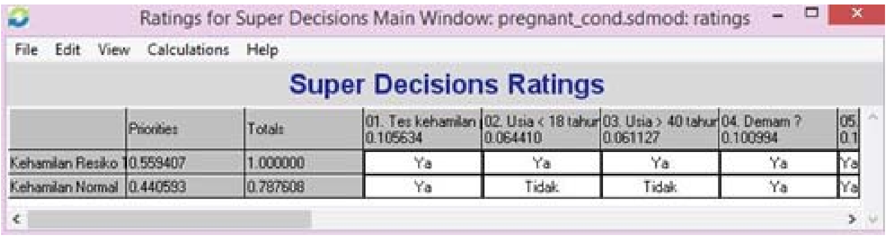


Figure 8. Super Decision Rating

After entering weighting values in the priorities table as described in Figure 8, we can run the program and get the results as described in Figure 9.

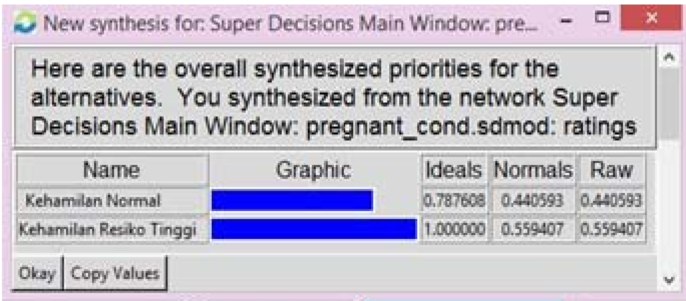


Figure 9. Results of SuperDecision

According to Figure 9, we achieved a performance rate of 79%, while in our system we got 80% performance. This means that our system is quite similar to the existing system in SuperDecision. Therefore our system is promising for implementation in real conditions, especially for ordinary people.

## 4. Conclusion

Our system is low-cost and easy for everyone to use, even if they are not from the medical field. Our system is also compatible for use on all types of computers because the software was developed using only Excel, where we can be sure that all computers have the Excel tool, so it is easy to access the system. However, even though it is a simple system, our system can still be developed to be a better system and can even be developed for mobile-based devices. Our system is also accurate. This has has been proven by the fact that our system has quite similar performance to the existing system in SuperDecision. Referring to the advantages of our system, we conclude that our system is promising for implementation in rural areas as a simple screening system for high-risk pregnancy. It is expected that by using this system, we can improve the quality of life for pregnant women in the developing countries.

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