ISSN 1913-1844(Print)
ISSN 1913-1852(Online)

# MODERN APPLIED SCIENCE

Vol. 7, No. 1 January 2013

CANADIAN CENTER OF SCIENCE AND EDUCATION

# Editorial Board

# Contents

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# Right-turn Bypass Lanes at Roundabouts: Geometric Schemes and Functional Analysis

Raffaele Mauro[1] & Marco Guerrieri[2]

[1] University of Trento, Department of Civil, Environmental and Mechanical Engineering, Trento, Italy

[2] University of Enna "Kore", Faculty of Engineering and Architecture, Enna, Italy

Correspondence: Marco Guerrieri, University of Enna "Kore", Faculty of Engineering and Architecture, Via della Cooperazione, Enna Bassa 94100, Enna, Italy. Tel: 39-935-536-350. E-mail: marco.guerrieri@tin.it

Received: November 8, 2012 Accepted: December 3, 2012 Online Published: December 7, 2012

doi:10.5539/mas.v7n1p1 URL: http://dx.doi.org/10.5539/mas.v7n1p1

**Abstract**

Right-turn bypass lanes can be implemented in conventional and innovative roundabout intersections to increase the capacity and improve the global functional performances. The Right-turn bypass lanes (also called slip lanes) can be distinguished according to the planimetric layout and the entry control type (stop, yield slip or Free Flow acceleration lane). This paper presents a closed-form model for the estimation of capacity, delays and level of service of roundabout equipped with Right-turn bypass lanes, considering the effect of geometric slip lane schemes, control type, vehicular and pedestrian flow. In order to examine the traffic conditions which can benefit from slip lane roundabouts in terms of capacity and delays, compared to traditional schemes which have no additional lanes, a great number of analyses have been carried out by considering different O/D matrices and vehicle and pedestrian flow vectors. Such comparisons have been made by considering the control delays in function of different O/D matrices. Such O/D matrices describe the most significant situations of traffic demand which can be of interest for the road intersections under study.

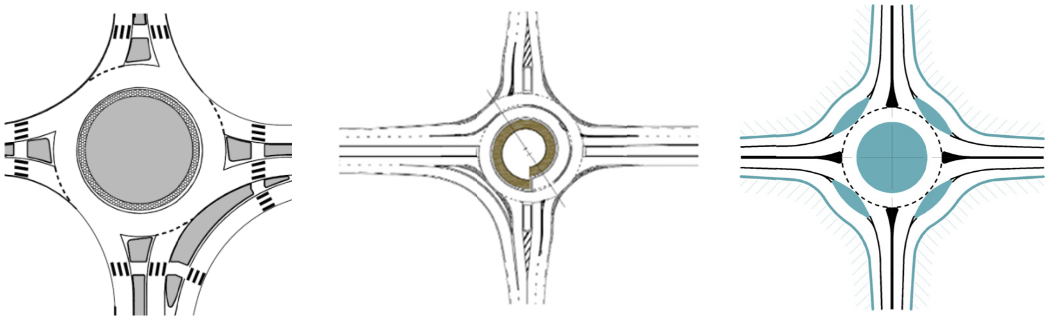
**Keywords:** right-turn bypass lanes, geometric layout, capacity, delay and level of service

## 1. Introduction

It is known that in case of heavy right-turn flows, slip lanes can be implemented to increase the compact and mini single-lane roundabout capacity (NCHRP Report 672, 2010) (see Figure 1a). The additional right-turn slip lanes are also used to configure turbo roundabouts (Turborotondes - CROW, 2008; Fortuijn, 2009) and flower roundabouts (Tollazzi et al., 2011; Al-Ghandour et al., 2012) (see Figures 1b and 1c). In flower roundabouts actually the geometry and performance are characterized by slip lanes at each leg (Tollazzi et al., 2011). In urban and sub-urban areas, with bicycle and pedestrian activity, a right-turn bypass lane should be implemented only where needed because the entries and exits of bypass lanes can increase conflicts with pedestrians, bicyclists and with merging on the downstream leg. However, in locations with low pedestrian and bicycle activity, slip lanes can be used to improve capacity when heavy right-turning traffic exists (NCHRP Report 672, 2010; FHWA, 2004).

There are various right-turn slip lane types. They can be distinguished according to the planimetric layout, the position respect to the ring lane, the merging modes with the roundabout entry leg and the entry control type into the roundabout exit leg. As for the control type, there are stop and yield slip lanes (Figure 2), different from those with an acceleration lane (Figure 4). The guidelines for design the geometric elements of slip lanes have been provided by kinematic considerations and by taking into account the waiting phenomena in the end sections. For details on the different slip lanes configurations, see NCHRP Report 672 and HCM 2010, as examples.

In this paper we are examined the geometric schemes of slip lanes shown in Figures 2 and 4. The slip lane type has effects on the global roundabout performance which can be also very different. A crucial role in bringing about these effects is played by the control type of exit flows from a slip lane. The capacity determination, the queue lengths and delays (measures of effectiveness, MOE) in right-turn slip lane roundabouts generally is carried out through traffic micro simulation (Al-Ghandour et al., 2012). This paper will show that, as a matter of fact, by considering the results developed as closed-form expressions through the queuing theory, it is possible to estimate if and which effects the slip lane geometry and control type (e.g. slip lane composition and length) can have on roundabout MOE. The calculation model developed in this paper includes the various single-lane roundabout types equipped with right-turn slip lanes controlled by stop or yield signs or with an acceleration lane ("*Free Flow slip lane*"). Moreover, in order to identify the traffic conditions which justify more considerable financial costs to build slip lanes (Mauro & Cattani, 2012) a great number of comparisons have been made between the different geometric patterns. Such comparisons have been made by considering the vehicles delays in function of different O/D matrices. Such O/D matrices describe the most significant situations of traffic demand which can be of interest for the designs under study.



a) Bypass lane at conventional roundabout b) Bypass lane at turbo roundabout c) Bypass lane at Flower roundabout

Figure 1. Bypass lanes at roundabouts

## 2. Slip Lane without an Acceleration Lane (with Stop or Yield Signs)

This slip lane type has the same geometric design as in Figure 2. The total right-turn flow is denoted with $Q_{E,R}$ while that one through the slip lane is indicated with $Q_{E,R}^{bypass}$. The antagonist flow of $Q_{E,R}^{bypass}$ exiting from the roundabout is denoted with $Qu^{Tot}$. For instance, with reference to leg 4, in Figure 2, it follows that $Qu^{Tot} = Q_{1,4} + Q_{2,4} + Q_{E,R}^{no\text{-}bypass}$; $Q_{E,R}^{no\text{-}bypass} = Q_{3,4} - Q_{E,R}^{bypass}$. It similarly occurs to $Qu^{Tot}$ related to the other legs.

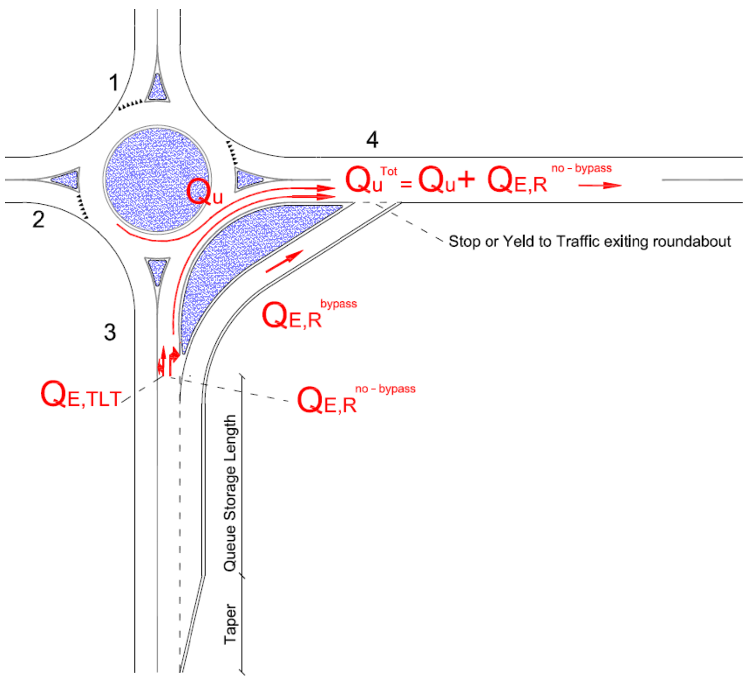



Figure 2. Entry, circulating and exit flows at roundabout (Stop or Yeld to traffic exiting)

### *2.1 Slip Lanes with a Stop Sign*

In the absence of specific indications from the guidelines, let us determine the stop slip lane capacity $C_{E,R}$ by means of some results from the Queuing Theory. Thus, $C_{E,R}$ is equal to the reciprocal of the average $b = E[s]$ of the service time *s* estimated at the merging slip lane section into the leg coming from the roundabout. In the event of Poisson vehicle arrivals for $Q_{E,R}^{bypass}$, any service time *s* and vehicle headways τ for the flow $Qu^{Tot}$ distributed like a Gamma random variable with a parameter K (Mauro & Branco, 2012), according to *P-K relationships* (Pollaczek, 1930; Khinchine, 1932; Kleinlock, 1975), b = E[s] can be calculated as following:

$$b = T + \frac{e^{KQT} - \sum_{i=0}^{K} \frac{(KQT)^i}{i!}}{Q \cdot \sum_{i=0}^{K-1} \frac{(KQT)^i}{i!}} \quad (1)$$

where: T = critical gap [s]; Q = $Qu^{Tot}$ [veh/h]; K = 1 if 100 ≤ Q ≤ 300 veh/h; K = 2 if 400 ≤ Q ≤ 800 veh/h; K = 3 if 800 ≤ Q ≤ 1500 veh/h, K = 4 if 1500 < Q ≤ 1800 veh/h.

By means of (1) $C_{E,R}$ follows as:

$$C_{E,R} = \frac{1}{T + \frac{e^{KQT} - \sum_{i=0}^{K} \frac{(KQT)^i}{i!}}{Q \cdot \sum_{i=0}^{K-1} \frac{(KQT)^i}{i!}}} \quad (2)$$

The critical gap can be calculated by means of the following relation:

$$T = \frac{V}{2 \cdot a} + 2 \cdot \delta \quad (3)$$

where V is the vehicle speed on $Qu^{Tot}$, *a* the acceleration by which $Q_{E,R}^{bypass}$ vehicles enter into the flow $Qu^{Tot}$; δ is the safety time interval between the vehicles of this flow, equal to the *Perception-Reaction Time* δ =1 s. V can be calculated through the procedure shown in NCHRP Report 672 in function of deflection radius of the vehicle trajectories passing through ring lane $R_2$ and coming from ring lane $R_3$. For the dimensions of compact single-lane roundabouts considered in this paper, $R_2$ and $R_3$ are generally included in the intervals 12 m ≤ $R_2$ ≤ 18 m and 23 m ≤ $R_3$ ≤ 29 m. With $R_2$ and $R_3$ values included in the previous intervals, V determinations near to V = 30 km/h can be obtained. As for the vehicle merging manoeuvre of $Q_{E,R}^{bypass}$ into the flow $Qu^{Tot}$ controlled by a stop sign, T is assumed as T = 5.5 s. By means of the values of V and δ previously indicated, with T = 5.5 s from (3) the acceleration *a* kept while merging can be obtained as follows a = 1.2 m/s$^2$.

By means of T = 5.5 s from (2) it is possible to obtain for the stop-controlled slip lane capacity $C_{E,R}$ the values in function of $Qu^{Tot}$ shown in Figure 3. These values are well least-squares interpreted from the relation:

$$C_{E,R} = 1231{,}4 \cdot e^{-0{,}0012 \cdot Qu^{Tot}} \quad (R^2 = 0.91) \quad (4)$$

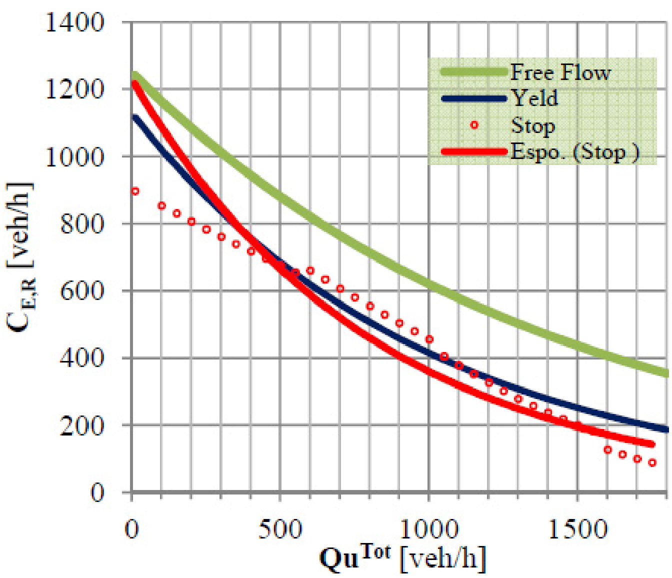



Figure 3. Free Flow, Yeld and Stop slip lane capacity

*2.2 Right-turn Yield Slip Lanes*

In this case the geometric layout is similar to that of stop-controlled slip lanes (Figure 2); the capacity formula is described in NCHRP Report 672:

$$C_{E,R} = 1130 \cdot e^{-0,001 \cdot Qu^{Tot}} \quad (5)$$

It is illustrated in Figure 3 along with the stop-controlled slip lane capacity. Figure 3 shows that the yield slip lane capacity is usually higher than that with a stop control.

## 3. Slip Lane with an Entry Lane (Free–flow Slip Lane)

This slip lane type is generally shown as in Figure 4. There are free-flow slip lane configurations which have an exit section as short as 30 m, for instance as provided for by Polish Road Intersections Design Guidelines - Part II, 2001. As in stop and yield-controlled slip lanes, the right-turn flow into the slip lane is denoted with $Q_{E,R}^{bypass}$; the antagonist flow of $Q_{E,R}^{bypass}$ from the roundabout is indicated with $Qu^{Tot}$ (Figure 4).

The HCM 2010 Manual for free-flow slip lanes does not provide the capacity formulations but it qualitatively estimates capacity values higher than those obtained by Yeld-controlled slip lanes. The following relation (6) has been obtained from Tracz (Tracz, 2008; Tracz et al., 2011) for free-flow slip lanes at single-lane roundabouts:

$$C_{E,R} = 1250 \cdot e^{-0,0007 \cdot Qu^{Tot}} \quad (6)$$

The relation (6) is illustrated in Figure 3.

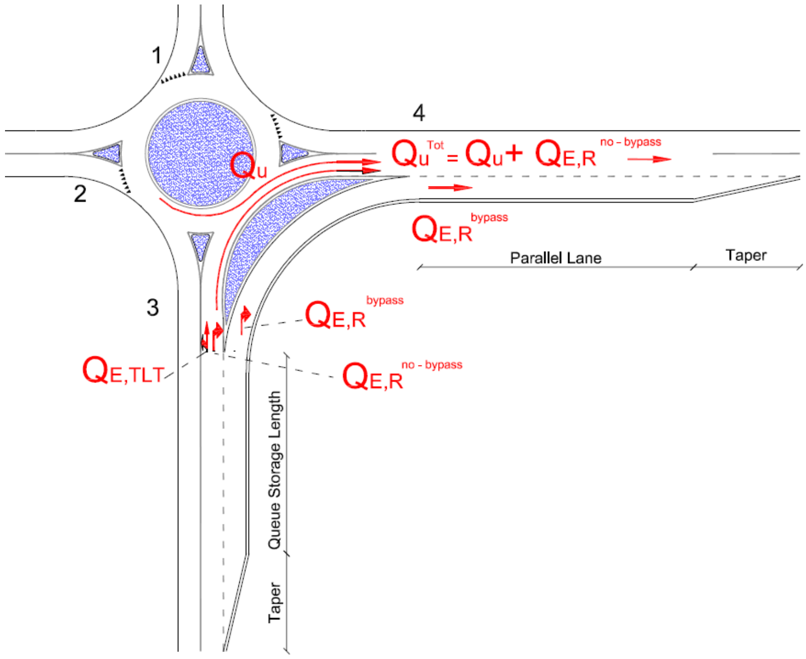



Figure 4. Entry, circulating and exit flows at roundabout (free flow bypass lane)

## 4. Effect of Pedestrian Flow on Slip Lane Capacity

The presence of pedestrian crossings reduces entry and exit capacity of slip lanes (there are generally 2 pedestrian crossings at each slip lane: the former that lies adjacent to the entry to the roundabout, the latter at the exit leg). In order to take these entry effects into consideration, the analyses carried out in this paper have adopted Brilon's formula (Brilon et al., 1993):

$$C_{E,R}^{ped-Entry} = C_0 \cdot M_{E,R}^{Entry} \quad (7)$$

$$M_{E,R}^{Entry} = (1119,5 - 0,715 \cdot Q_u^{Tot} - 0,644 \cdot Q_{ped}^{Entry} + 0,00073 \cdot Q_u^{Tot} \cdot Q_{ped}^{Entry}) / (1069 - 0,65 \cdot Q_u^{Tot}) \quad (8)$$

where:

$M_{E,R}^{Entry}$ = right-turn lane pedestrian capacity reduction factor;

$C_{E,R}^{ped\text{-}Entry}$ = by-pass capacity, impact of pedestrians considered at Entry [veh/h];

$C_0$= slip lane capacity assumed as equal as 1250 veh/h (generally, $C_0$ value ranges from 1200 to 1400 veh/h);

$Q_{ped}^{Entry}$ = pedestrian flow at Entry [ped/h]

In order to determine the slip lane capacity at pedestrian crossings in roundabout exit legs $C_{E,R}^{ped\text{-}Exit}$, Marlow and Maycock formula (Marlow & Maycock, 1982) has been adopted:

$$C^{ped-Exit} = \frac{Q_{ped}^{Exit}}{Q_{ped}^{Exit}\cdot\beta + (e^{Q_{ped}^{Exit}\cdot\alpha}-1)\cdot(1-e^{-Q_{ped}^{Exit}\cdot\beta})}\cdot 3600 \tag{9}$$

$$\beta = \frac{1}{C_{E,R}^{ped-Entry}} \tag{10}$$

$$\alpha = \frac{B}{v_{ped}} \tag{11}$$

$$R = \frac{C^{ped-Exit}}{C_0} \tag{12}$$

$$M_{E,R}^{Exit} = \frac{R^{N+2}-R}{R^{N+2}-1} \tag{13}$$

$$C_{E,R}^{ped-Exit} = C_0 \cdot M_{E,R}^{Exit} \tag{14}$$

where:

$C^{ped\text{-}Entry}$ = capacity in the presence of only pedestrian traffic;

$v_{ped}$ = average speed of the pedestrian traffic [m/s], generally equal to 1.4 m/s on average;

B = length of a pedestrian crossing [m];

$C_0$= slip lane capacity assumed as equal as 1250 veh/h (generally, $C_0$ value ranges from 1200 to 1400 veh/h);

N = number of vehicles queuing in the area between the pedestrian crossing and the yield line. N is function of a median longitudinal space occupied by a vehicle (equal to 5÷6 m).

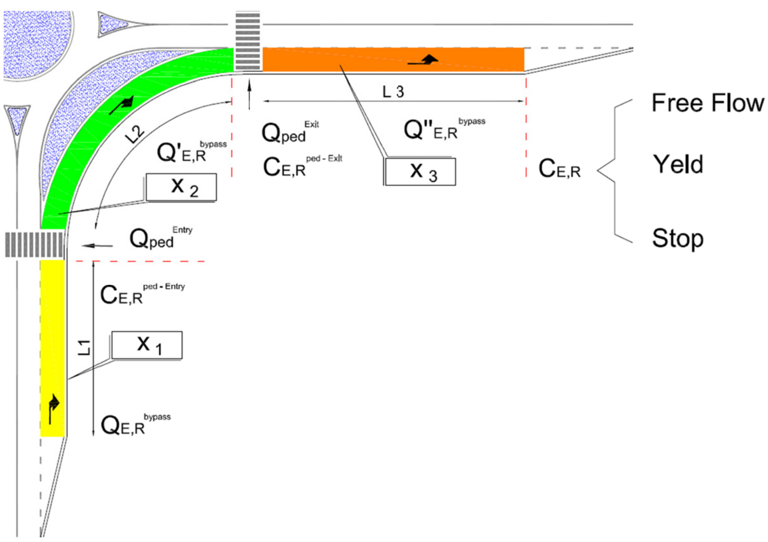



Figure 5. Flows, capacities and degree of saturation on slip lane

The presence of the two pedestrian crossings on the slip lane (the former on the entry leg, the latter on the exit leg from the roundabout) together with the entry (controlled by stop or yield signs, or free-flow) determines three distinct road sections, each with its own function. More specifically, according to the vehicular direction, there follows one after another (see Figure 5):

- Section 1 (of length L1) with capacity $C_{E,R}^{ped\text{-}Entry}$, flow $Q_{E,R}^{bypass}$ and saturation degree $x_1$;
- Section 2 (of length L2) with capacity $C_{E,R}^{ped\text{-}Exit}$, flow $Q'_{E,R}^{bypass}$ and saturation degree $x_2$;
- Section 3 (of length L3) with capacity $C_{E,R}$, flow $Q''_{E,R}^{bypass}$ and saturation degree $x_3$;

Since the three sections are in sequence, the following conditions need to be verified:

$$x_1 = \frac{Q_{E,R}^{bypass}}{C_{E,R}^{ped-Entry}} \tag{15}$$

$$Q'_{E,R}^{bypass} = \min\left(Q_{E,R}^{bypass};\ C_{E,R}^{ped\text{-}Entry}\right) \tag{16}$$

$$x_2 = \frac{Q'_{E,R}^{bypass}}{C_{E,R}^{ped-Exit}} \tag{17}$$

$$Q'_{E,R}^{bypass} = \min\left(Q'_{E,R}^{bypass};\ C_{E,R}^{ped\text{-}Exit}\right) \tag{18}$$

$$x_3 = \frac{Q''_{E,R^{bypass}}}{C_{E,R}} \tag{19}$$

where $C_{E,R}$ is calculated by means of expressions (4), (5), (6) according to the slip lane control type. The degree of saturation in a slip lane (required for the estimation of the Total Entry Capacity) corresponds to the maximum value of $x_1$, $x_2$, $x_3$:

$$x_{E,R} = \max\left(x_1,\ x_2,\ x_3\right) \tag{20}$$

As an example, Figure 6 shows the values of saturation degrees (x1, x2, x3) of a yield-controlled slip lane under varying pedestrian flow intensity ($Q_{ped}^{Exit}$ = 50 ÷ 850 ped/h) in the following traffic conditions: $Q_u^{Tot}$ = 800 veh/h, $Q_{ped}^{Entry}$ = 200 ped/h; $Q_{E,R}^{bypass}$ = 600 veh/h. Section L3 (see Figure 5) has also been assumed to be 60 m long.

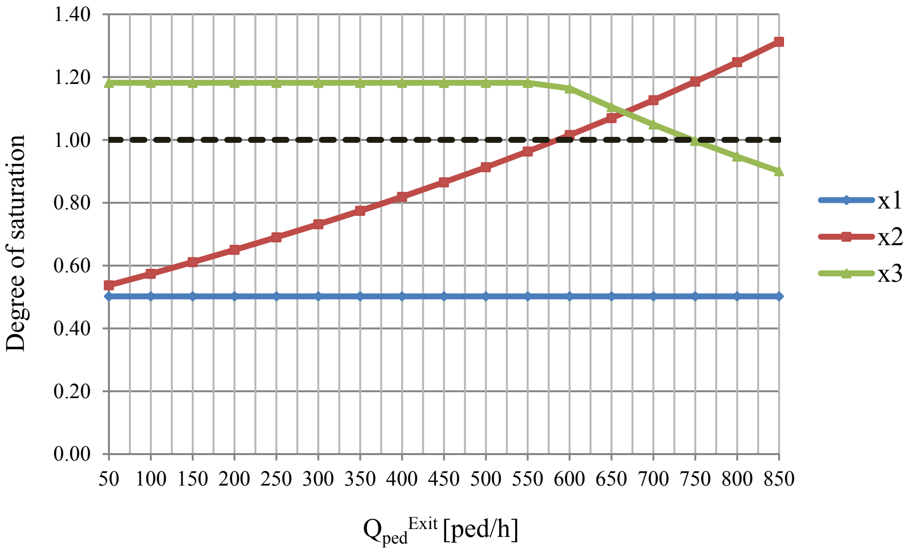



Figure 6. Values of the degree of saturation (bypass with yeld signal)

## 5. Capacity of the Merging Lane with the Ring Road

The entry lane capacity to the ring $C_{E,TLT}$ can be determined through the formulation provided for by the HCM 2010 for roundabouts with a single lane at entries and a single lane at the ring; by denoting the circulating flow with Qc it follows that:

$$C_{E,TLT} = 1130 \cdot e^{\left(-1,0\cdot 10^{-3}\right)\cdot Q_c} \tag{21}$$

In order to take the pedestrian flow into consideration, Brilon's formula is used (Brilon et al., 1993):

$$C_{E,TLT}^{ped} = C_{E,TLT} \cdot M_{E,TLT} \tag{22}$$

$$M_{E,TLT} = (1119{,}5 - 0{,}715 \cdot Q_c - 0{,}644 \cdot Q_{ped} + 0{,}00073 \cdot Q_c \cdot Q_{ped}) / (1069 - 0{,}65 \cdot Q_c) \tag{23}$$

$M_{E,TLT}$ = through and left-turn lane pedestrian capacity reduction factor;

$C_{E,TLT}{}^{ped}$ = through and left-turn lane vehicle capacity, impact of pedestrians considered [veh/h];

$C_{E,TLT}$ = through and left-turn lane vehicle capacity (no pedestrians crossing, only vehicles) [veh/h];

The respective saturation degree of a lane is given by:

$$x_{E,TLT} = \frac{Q_{E,TLT} + Q_{E,R}{}^{no-bypass}}{C_{E,TLT}{}^{ped}} \tag{24}$$

## 6. Total Entry Capacity

After obtaining the entry lane capacity of a slip lane, by denoting the saturation degrees (entry flow/capacity ratio) with x, the entry capacity ($C_E{}^{ped}$) can be estimated through the following relation (Mauro & Branco, 2010; Corriere & Guerrieri, 2012; Giuffrè et al., 2012):

$$C_E{}^{ped} = \frac{(Q_{E,R} + Q_{E,TLT})}{\max[x_{E,R}; x_{E,TLT}]} \tag{25}$$

Where $Q_{E,R}$, $Q_{E,TLT}$, $x_{E,R}$, $x_{E,TLT}$ are respectively flows and degree of saturation at the two lanes of the entry E.

## 7. Determination of Delays, Levels of Service and Length of the Queue

Once the capacity and saturation degrees of entry lanes have been obtained, it is possible to determine the delays and the levels of service for each lane and the entry itself. To this end, the following relations contemplated by the Manual HCM 2010 can be applied, suitably modified to take any pedestrian flow into consideration:

$$D_{E,TLT}{}^{ped} = \frac{3600}{C_{E,TLT}{}^{ped}} + 900 \cdot T \cdot \left[ \frac{Q_{E,TLT}}{C_{E,TLT}{}^{ped}} - 1 + \sqrt{\left(\frac{Q_{E,TLT}}{C_{E,TLT}{}^{ped}} - 1\right)^2 + \frac{\left(\frac{3600}{C_{E,TLT}{}^{ped}}\right) \cdot \left(\frac{Q_{E,TLT}}{C_{E,TLT}{}^{ped}}\right)}{450 \cdot T}} \right] + 5 \cdot \min\left[\frac{Q_{E,TLT}}{C_{E,TLT}{}^{ped}}, 1\right] \tag{26}$$

$$D_{E,R}{}^{ped} = \frac{3600}{C_{E,R}{}^{ped}} + 900 \cdot T \cdot \left[ \frac{Q_{E,R}}{C_{E,R}{}^{ped}} - 1 + \sqrt{\left(\frac{Q_{E,R}}{C_{E,R}{}^{ped}} - 1\right)^2 + \frac{\left(\frac{3600}{C_{E,R}{}^{ped}}\right) \cdot \left(\frac{Q_{E,R}}{C_{E,R}{}^{ped}}\right)}{450 \cdot T}} \right] + 5 \cdot \min\left[\frac{Q_{E,R}}{C_{E,R}{}^{ped}}, 1\right] \tag{27}$$

$$D_E{}^{ped} = \frac{D_{E,R}{}^{ped} \cdot Q_{E,R} + D_{E,TLT}{}^{ped} \cdot Q_{E,TLT}}{Q_{E,R} + Q_{E,TLT}} \tag{28}$$

where $D_{E,R}{}^{ped}$, $Q_{E,R}$, $D_{E,TLT}{}^{ped}$, $Q_{E,TLT}$ are respectively delays and flow rates at the two lanes of the entry E. T is the reference time (T = 1 for 1-hour analysis; T = 0.25 for 15-minute analysis). The levels of service referred to the delay values obtained by means of the previous relations (26), (27) and (28) are shown in Table 1 (HCM, 2010).

As an example, Figure 7 below indicates the value assumed by the mean control delay for an entry to the roundabout with a slip lane under varying saturation degrees in the following traffic conditions: $Q_c$ = 750 veh/h; $Q_{ped}{}^{Entry}$ = 50 ped/h; $Q_{ped}{}^{Exit}$ = 50 ped/h; $Q_u{}^{Tot}$ = 500 veh/h. Whenever traffic changes, surfaces similar to those in Figure 7 are obtained.

Table 1. Level of service

| Control Delay | Q/C ≤ 1 | Q/C ≥ 1 |
|---|---|---|
| 0-10 | A | F |
| 10-15 | B | F |
| 15-25 | C | F |
| 25-35 | D | F |
| 35-50 | E | F |
| > 50 | F | F |

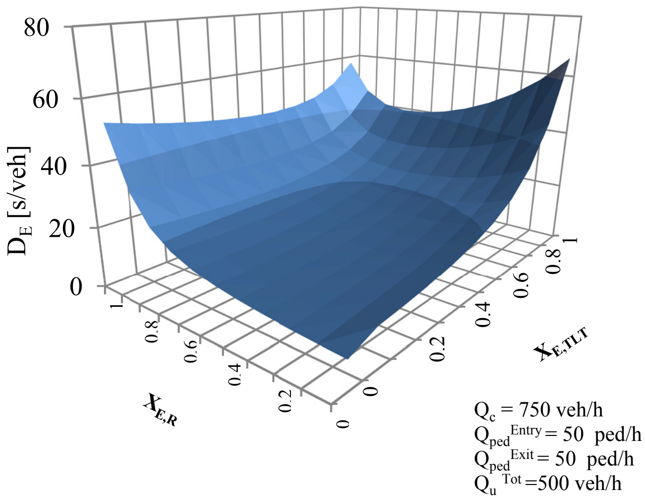



Figure 7. Entry mean control delay

## 8. Functional Comparison

In order to identify the traffic conditions which make roundabouts with a right-turn slip lane more advantageous than conventional roundabouts in terms of functionality, specific analyses have been carried out for different O/D matrices. It is noteworthy to point out that if there is a right-turn slip lane at each leg, the functional geometric layout has the same behaviour as in flower roundabouts (see Figure 1c).

The geometric layouts compared to one another are the following:

- Roundabouts with stop-controlled slip lanes (at each leg);
- Roundabouts with yield-controlled slip lanes (at each leg);
- Roundabouts with Free-flow slip lanes (at each leg);
- Conventional roundabouts with a single lane at entries and a single lane at the ring – layout (1+1);
- Conventional roundabouts with a single lane at entries and a double lane at the ring – layout (1+2);
- Conventional roundabouts with a double lane at entries and a double lane at the ring – layout (2+2).

In order to determine the capacities, the following formulations have been used:

- Equation (4) for roundabouts with a stop-controlled slip lane;
- Equation (5) for roundabouts with a yield-controlled slip lane;
- Equation (6) for roundabouts with a free-flow slip lane;
- The formula suggested by the HCM 2010 Manual for conventional roundabouts with a single lane at entries and 1 lane at the ring – layout (1+1):

$$C_E = 1130 \cdot e^{-0,0001 \cdot Qc} \quad (29)$$

- The formula suggested by the HCM 2010 Manual for conventional roundabouts with a single lane at entries and two lanes at the ring – layout (1+2):

$$C_E = 1130 \cdot e^{-0,007 \cdot Qc} \quad (30)$$

- The formulas suggested by the HCM 2010 Manual for conventional roundabouts with a double lane at entries and a double lane at the ring – layout (2+2). For the two lanes at entries the formulas are the following:

$$C_{E,R} = 1130 \cdot e^{-0,0007 \cdot Qc} \quad (31)$$

$$C_{E,TLT} = 1130 \cdot e^{-0,00075 \cdot Qc} \quad (32)$$

For each layout under study the mean control delays have been determined by employing Equations (26) (27) and (28). The traffic conditions examined are the following:

- *O/D Matrices - Origin/destination matrices of traffic flows in percentage terms* - (the leg numeration is illustrated in Figure 2 and Figure 4): ρ1 considers a majority of vehicles going ahead; the same occurs in ρ2 but left-turn percentages are 25%. Matrix ρ3 indicates a clear majority of crossings for flows 2 and 4 and very limited left-turns, ρ4 e ρ5 indicate two or one direction of preferential exit. Matrix ρ6 assumes that most users turn to the right (70% out of the total);

- *Vehicular flow vectors*. Q3 flows are basically the same on the four legs, Q2 flows especially move in direction 1-3; Q1 is an intermediate situation between Q3 and Q2; Q4 indicate very unbalanced flows.
- *Pedestrian flow vectors:* Qp1 and Qp2: pedestrian flows of average/high intensity; Qp3: very low pedestrian flows.

$$\rho 1 = \begin{vmatrix} 0 & 0{,}15 & 0{,}74 & 0{,}11 \\ 0{,}19 & 0 & 0{,}24 & 0{,}57 \\ 0{,}63 & 0{,}15 & 0 & 0{,}22 \\ 0{,}19 & 0{,}74 & 0{,}07 & 0 \end{vmatrix} \qquad \rho 2 = \begin{vmatrix} 0 & 0{,}15 & 0{,}60 & 0{,}25 \\ 0{,}2 & 0 & 0{,}20 & {,}55 \\ 0{,}60 & 0{,}25 & 0 & 0{,}15 \\ 0{,}30 & 0{,}50 & 0{,}20 & 0 \end{vmatrix}$$

$$\rho 3 = \begin{vmatrix} 0 & 0{,}15 & 0{,}70 & 0{,}15 \\ 0{,}02 & 0 & 0{,}18 & 0{,}80 \\ 0{,}70 & 0{,}15 & 0 & 0{,}15 \\ 0{,}18 & 0{,}80 & 0{,}02 & 0 \end{vmatrix} \qquad \rho 4 = \begin{vmatrix} 0 & 0{,}125 & 0{,}75 & 0{,}125 \\ 0{,}375 & 0 & 0{,}375 & 0{,}25 \\ 0{,}75 & 0{,}125 & 0 & 0{,}125 \\ 0{,}375 & 0{,}25 & 0{,}375 & 0 \end{vmatrix}$$

$$\rho 5 = \begin{vmatrix} 0 & 0{,}25 & 0{,}75 & 0{,}125 \\ 0{,}125 & 0 & 0{,}625 & 0{,}25 \\ 0{,}5 & 0{,}25 & 0 & 0{,}\ 25 \\ 0{,}125 & 0{,}25 & 0{,}625 & 0 \end{vmatrix} \qquad \rho 6 = \begin{vmatrix} 0 & 0{,}7 & 0{,}2 & 0{,}1 \\ 0{,}2 & 0 & 0{,}7 & 0{,}1 \\ 0{,}1 & 0{,}3 & 0 & 0{,}6 \\ 0{,}7 & 0{,}2 & 0{,}1 & 0 \end{vmatrix}$$

$$\begin{aligned} [Q1] &= [300 \quad 200 \quad 500 \quad 400] \\ [Q2] &= [386 \quad 182 \quad 410 \quad 446] \\ [Q3] &= [436 \quad 428 \quad 410 \quad 446] \\ [Q4] &= [100 \quad 500 \quad 100 \quad 500] \end{aligned}$$

$$\begin{aligned} [Qp\ 1] &= [50 \quad 100 \quad 50 \quad 100] \\ [Qp\ 2] &= [150 \quad 300 \quad 150 \quad 300] \\ [Qp\ 3] &= [10 \quad 10 \quad 10 \quad 10] \end{aligned}$$

For each traffic condition examined, the vehicle flows entering the roundabout have been increased from value 0 to the value which determines the reaching of the roundabout *simple capacity* with regard to the geometric design which, each time, offers the highest capacity. It is noted that roundabouts with slip lane allow a significant delay reduction in all the flow conditions compared to conventional roundabouts with a single lane at entries (layouts (1+1) and (1+2)). On the contrary, compared with multilane roundabouts (2+2) their performances are lower, up to 70% of the total right-turn flows. Once such a threshold is exceededand according to the pedestrian flow intensity, it can be more convenient to use slip lane roundabouts than all the other designs. Moreover, free-flow slip lanes prove to be more advantageous than those controlled by stop or yield signs; this is consistent with the results shown by Al-Ghandour (Al-Ghandour et al., 2012). The following figures elucidate the above points. More specifically, if right-turn percentage is lower than 70% (Figures 8, 9, 10 and 11), roundabouts with slip lanes cause intermediate delays between roundabouts with the geometric schemes (1+2) and (2+2). On the contrary, when the right-turn percentage is higher or equal to 70% of the total (see Figures 12 and 13), slip lane roundabouts can cause delays inferior to those observed in the other configurations examined. In case of moderate pedestrian flow (Qp3), only roundabouts with free-flow slip lanes can cause delays inferior to those with double lanes. If, on the contrary, the pedestrian flow is high (Qp2), the performances of roundabouts with right-turn bypass lanes are the best among all the configurations, regardless of their control type.

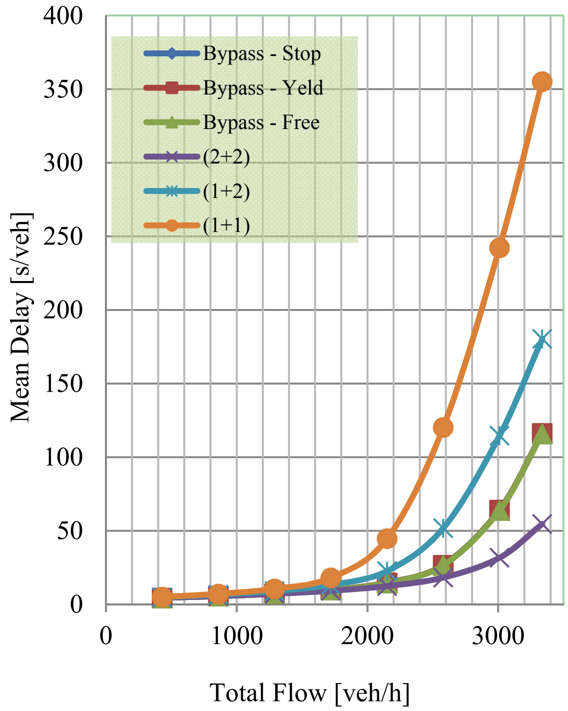



Figure 8. Roundabouts mean delay - Scenario: ρ1, Q1, Qp1

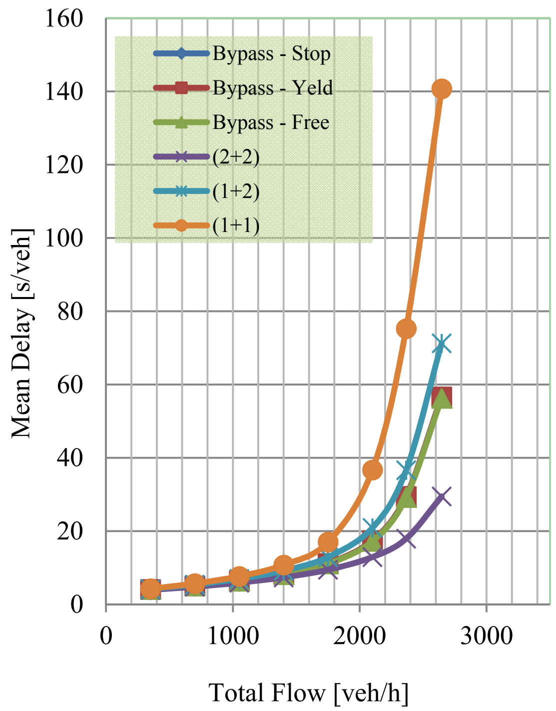



Figure 9. Roundabouts mean delay - Scenario: ρ1, Q1, Qp2

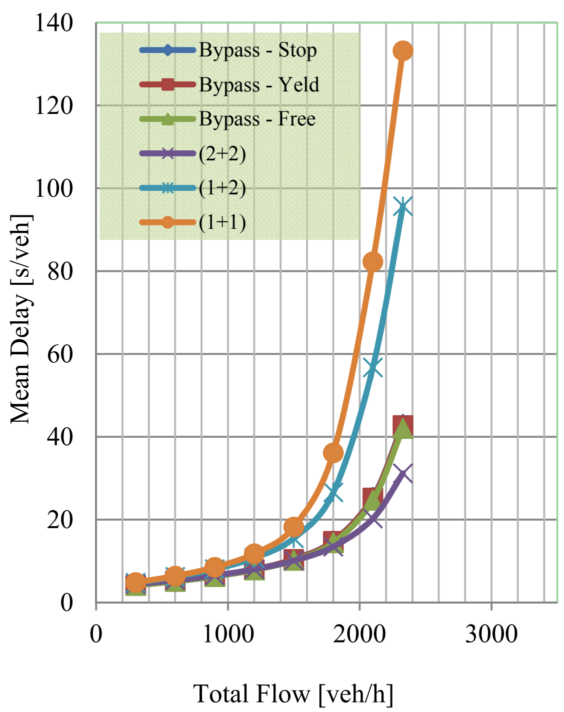



Figure 10. Roundabouts mean delay - Scenario: ρ1, Q3, Qp2

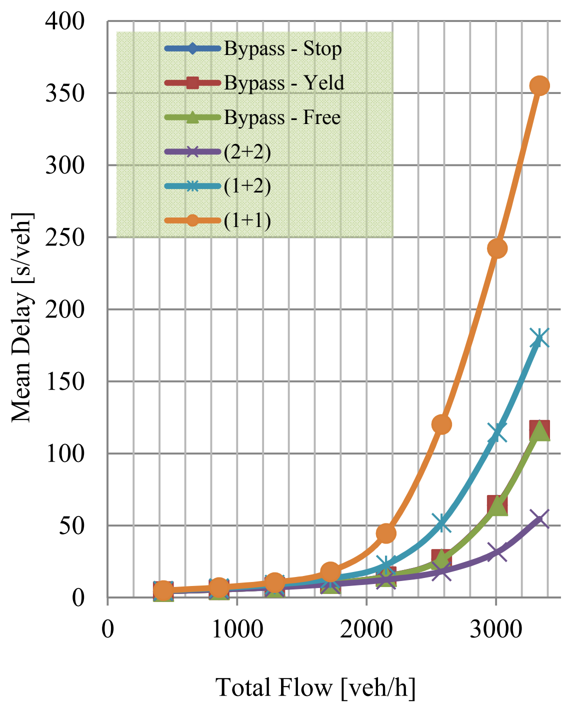



Figure 11. Roundabouts mean delay - Scenario: ρ4, Q3, Qp2

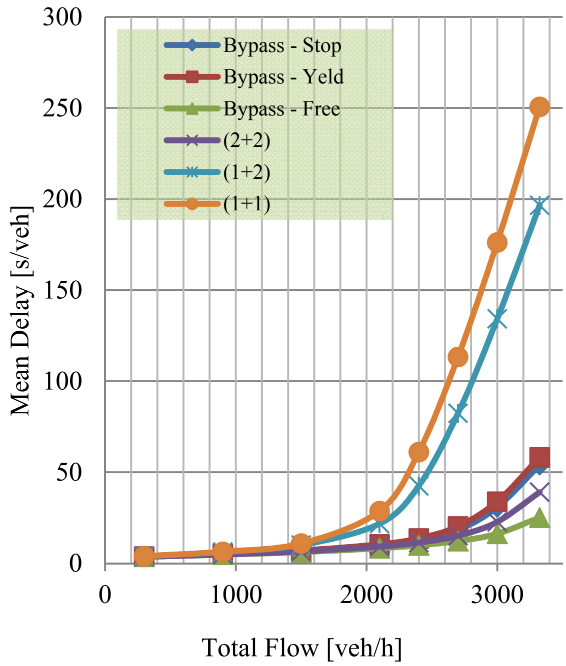



Figure 12. Roundabouts mean delay - Scenario: ρ6, Q4, Qp3

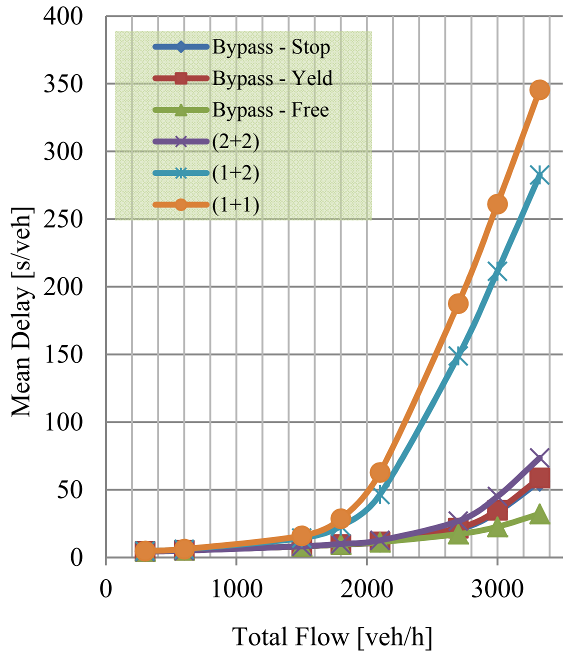



Figure 13. Roundabouts mean delay - Scenario: ρ6, Q4, Qp2

As for the effects of the distribution of right-turn flows on vehicle delays, also the case in which $Q_{E,R}^{no\text{-}bypass} \neq 0$ has been estimated. It follows that: $Q_{E,R}^{bypass} = \alpha' \cdot Q_{E,R}$; $Q_{E,R}^{no\text{-}bypass} = \beta \cdot Q_{E,R}$ ($0 \leq \alpha' \leq 1$; $0 \leq \beta \leq 1$; $\alpha + \beta = 1$). It has been observed that if right-turn manoeuvres prevail (like, for instance, with matrix ρ6) and with high pedestrian flows (Qp2), the distribution of right-turn flows between slip lanes and entry lanes can result in a modest reduction of average intersection delays. For instance, for ρ6, Q4, Qp2, in case of α' = 0.6 there is a maximum benefit of 2 seconds, as shown in Table 2 (yield-controlled slip lane compared to the case in which α' = 1). Such a circumstance can be explained by the fact that when α' < 1, if on the one hand there is a delay reduction in slip lanes, on the other there is a delay increase in lanes entering the roundabout.

Table 2. Values of the intersection mean delay [s/veh] as function of α'

| Total Entry | (ρ6, Q4, Qp2); α' = 1 | | | (ρ6, Q4, Qp2); α' = 0,6 | | |
|---|---|---|---|---|---|---|
| Flow [veh/h] | Stop | Yeld | Free | Stop | Yeld | Free |
| 300 | 5 | 5 | 5 | 4 | 4 | 4 |
| 600 | 5 | 5 | 5 | 5 | 5 | 5 |
| 1500 | 8 | 8 | 8 | 7 | 7 | 7 |
| 1800 | 10 | 10 | 10 | 9 | 9 | 8 |
| 2100 | 11 | 12 | 11 | 11 | 11 | 10 |
| 2700 | 21 | 22 | 17 | 22 | 20 | 15 |
| 3000 | 34 | 35 | 23 | 38 | 33 | 22 |

## 9. Conclusions

Right-turn slip lanes are employed to increase the capacity of roundabouts. Generally, the slip lane roundabout performances are evaluated through traffic simulations implemented with specialized software. This paper suggests a closed-form model for calculating the capacity and delays in slip lane roundabouts which takes into consideration a great number of geometric and traffic-regulating parameters, among which, slip lane dimensions, traffic control type (stop sign, yield sign, Free Flow), intensity and distribution of vehicle and pedestrian flows, saturation degrees of the lanes and so on. In order to examine the traffic conditions which can benefit from slip lane roundabouts in terms of capacity and delays, compared to traditional schemes which have no additional lanes, a great number of analyses have been carried out by considering different O/D matrices and vehicle and pedestrian flow vectors. The results of the analyses show that roundabouts with right-turn bypass lane lead to a significant delay reduction in any flow condition compared to conventional roundabouts with one lane at entries ((1+1) or (1+2) layouts). Compared to multilane roundabouts (2 ring lanes + 2 entry lanes), slip lane roundabouts cause more serious delays, in the case of right-turn flows up to 70% of the total. When such a threshold is exceeded slip lane roundabouts appear to be more convenient than any other design, in that the average vehicle delays decrease in a more and more marked manner in the presence of the same traffic volume. Moreover, among the slip lane types, those with a free-flow lane are more advantageous than those with a stop or yield sign. Finally, we have observed that the distribution of right-turn flows between a slip lane and a lane entering the roundabout ($\alpha' < 1$) can cause a slight reduction in the average intersection delays; this exclusively happens when the right-turn percentage is higher than 70%.

**References**

Al-Ghandour, M., Schroeder, B., Rasdorf, W., & Williams, B. (2012). *Delay Analysis of Single-Lane Roundabout with a Slip Lane under Varying Exit Types.* Experimental Balanced Traffic Volumes, and Pedestrians: Using Microsimulation, TRB, Annual Meeting.

Brilon W., Stuwe B., & Drews O. (1993). *Sicherheit und Leistungsfähigkeit von Kreisverkehrsplätzen*. Institute for Traffic Engineering, Ruhr Universität, Bochum (Deutschland).

Corriere, F., & Guerrieri, M. (2012). Performance analysis of basic turbo-roundabout in urban context. *Procedia - Social and Behavioral Sciences, 53*(3), 622-632. http://dx.doi.org/10.1016/j.sbspro.2012.09.912

FHWA. (2004). Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). *Improved Right-Turn Slip-Lane Design*. Report No. FHWA-SA-04-003.

Fortuijn, L. G. H. (2009). Turbo Roundabouts: Estimation of Capacity. *Transportation Research Record*, *2130*(2009), 83-92. http://dx.doi.org/10.3141/2130-11

Giuffrè, O., Granà, A., & Marino, S. (2012). Comparing Performances of Turbo-roundabouts and Double-lane Roundabouts. *Modern Applied Science, 6*(10), 70-79. http://dx.doi.org/10.5539/mas.v6n10p70

HCM. (2010). *Highway Capacity Manual* (ed.). Transportation Research Board, TRB.

Khintchine, A. Y. (1932). Mathematical theory of a stationary queue. *Matematicheskii Sbornik, 39*(4).

Kleinlock, L. (1975). *Queuing Systems, I*. New York: John Wiley and Sons.

Mauro, R., & Branco, F. (2010). Comparative Analysis of Compact Multilane Roundabouts and Turbo-Roundabouts. *Journal of Transportation Engineering, 136*(4), 316-322. http://dx.doi.org/10.1061/(ASCE)TE.1943-5436.0000106

Mauro, R., & Cattani, M. (2012). Functional and Economic Evaluations for Choosing Road Intersection Layout. *Promet–Traffic & Transportation, 24*(5). http://dx.doi.org/10.7307/ptt.v24i5.1180

Mauro, R., & Branco, F. (2012). Two Vehicular Headways Time Dichotomic Models. *Modern Applied Science, 6*(12), 1-12. http://dx.doi.org/10.5539/mas.v6n12p1

Marlow, M., & Maycock, G. (1982). The Effect of Zebra Crossings on Junction Entry Capacities. *Report SR 742, Transport and Road Research Laboratory (TRRL)*, Crowthorne, Berkshire, England.

NCHRP Report 672. (2010). *Roundabouts: An Informational Guide - Second Edition*, TRB.

Pollaczek, F. (1930). *Über eine Aufgabe der Wahrscheinlichkeitstheorie*. Mathematische Zeitschrift.

Tollazzi, T., Renčelj, M., & Turnšek, S. (2011). New Type of Roundabout: Roundabout with “Depressed” Lanes for Right Turning - “Flower Roundabout”. *Promet – Traffic & Transportation, 23*(5), 353-358.

Tracz, M. (2008). Analysis of Small Roundabouts’ Capacity. *National roundabout conference*, Kansas City, Missouri.

Tracz, M., Chodur, J., & Ostrowsk, K. (2011). Roundabouts Country report - Poland. *6th International Symposium on Highway Capacity and Quality of Service*, Stockholm.

*Turborotondes*, CROW publicatie 257, April 2008.

Wytyczne Projektowania Skrzyzowan Drogowych, Czesc II. (2001). Warszawa (*Road intersections design guidelines - Part II*).

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# Synthesizing Drainage Morphology of Tectonic Watershed in Upper Ing Watershed (Kwan Phayao Wetland Watershed)

Rangsan Ket-ord[1], Nipon Tangtham[2] & Veerasak Udomchoke[3]

[1] Faculty of Environment, Kasetsart University, Bangkok, Thailand

[2] Forest Research Center, Faculty of Forestry, Kasetsart University, Bangkok, Thailand

[3] Department of Earth Sciences, Faculty of Science, Kasetsart University, Bangkok, Thailand

Correspondence: Rangsan Ket-ord, Faculty of Environment, Kasetsart University, Bangkok 10900, Thailand. Tel: 66-8-9525-5469. E-mail: rangsank@gmail.com

Received: November 12, 2012 Accepted: December 1, 2012 Online Published: December 7, 2012

doi:10.5539/mas.v7n1p13 URL: http://dx.doi.org/10.5539/mas.v7n1p13

**Abstract**

The study was aimed to synthesize drainage morphology of tectonic watershed in upper Ing Watershed in Phayao province, northern Thailand. The morphometric analysis of 12 sub-watersheds was carried out using Geographic Information System (GIS) software-ArcGIS 9.3 for analysing drainage pattern and calculating the 16 theoretical values of drainage morphometric parameters in 3 aspects including linear aspect, areal aspect and relief aspect. The geologic formation and structure are also overlain on drainage morphological map to determine their influence on drainage patterns. The results showed that most areas were dendritic drainage pattern, while rectangular drainage pattern occurs relative to the direction of the fault. Trellis drainage pattern shown on the northeast of the watershed in Mae Puem sub-watershed which the rock layers bend or tilt in syncline structural geology. The upper Ing watershed was classified as a third to fifth order streams, which controlled by physiographic and structural conditions. The tectonic force formed a graben basin which Kwan Phayao wetland is the lowest area of this graben while the high mountain ranges in the western area. As a result, the river is flowing from western highland to lowland quickly especially in the western sub-watershed, this result affecting low permeability, high discharge of runoff and intensity of erosion processes which the calculated drainage morphometric parameters showed the results according to their appearance. It could be said that the drainage patterns in this area is influenced by tectonic structure rather than geologic formation. This study provided more understanding in drainage morphological characteristics of the upper Ing watershed for planning sustainable management of the Kwan Phayao wetland.

**Keywords:** drainage morphology, tectonic watershed, upper Ing watershed, Kwan Phayao wetland

## 1. Introduction

Upper Ing watershed lay on the north of Phi Pun Nam ranges, situated in the southern of Phayao-Chiang Rai basin, which is a part of Mekong watershed. The watershed was affected from tectonic forces that formed a graben along the fault. Kwan Phayao is the lowest area of this graben which accumulated water, sediments, nutrients, and poisonous substances. Kwan Phayao is very important for consumptions, fisheries, agricultures, and accommodated surplus flooding in rainy season. Moreover, its features indicated “a wetland” according to the international convention on wetlands (Ramsar Convention) (Office of natural resources and Environmental policy and planning, 1999). Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). Many workers have carried out morphometric analysis using remote sensing and geographic information system (GIS) techniques includes Vittala et al. (2004), Chopra et al. (2005), Narendra and Nageswararao (2006), Ozdemir and Bird (2009), Thomas et al. (2011), Chitra et al. (2011), Zende and Nagrajan (2011), and Magesh et al. (2012). This study aimed to understand the drainage morphology in upper Ing watershed. The 16 value of drainage morphometric parameters were calculated in 3 aspects include linear aspect, areal aspect, and relief aspect. The knowledge of this study will be beneficial to management of Kwan Phayao wetlands.

The objectives of this study consist of:

1) To study drainage pattern in upper Ing watershed which affected from geomorphological conditions and related to the fault directions in this area.

2) To analyze the drainage morphology by using GIS and synthesis the drainage patterns based on the related drainage morphological theories.

The result of this study can be divided into four parts. The first part is the patterns of drainage system; the second part is the drainage morphology; the third part is the drainage morphometric parameters of each drainage pattern; and the fourth part is geological structural control on drainage morphology.

## 2. Study Area

The upper Ing watershed is a part of Mekong watershed, located between 19°01′21″ to 19°32′53″ N in latitude and 99°41′24″ to 99°57′32″ E in longitude. The area of this watershed is 1,148.92 square kilometers, including MuangPhayao district, Mae Chai district, and some parts of Dok Kham Tai district. Furthermore, some areas are in Parn district and Phadad district in ChaingRai province, which Ing River is the main stream of this area. This watershed consists of 12 sub-watersheds, which is a plain in the middle of watershed. There are many large swamps such as Kwan Phayao and NongLengSai swamp. The highland and mountains are in the west side, while the areas between plain and highland are undulating and rolling phase. Those of topographical features were formed by tectonic forces which collapsed along the fault and occured a large graben. Thus, a lowest area of the graben is Kwan Phayao. The functions of this watershed are collecting and storing water and sediments that flowed from the highland in northwest and west side. Then, the IngRiver flows backward into Mekong River at Chaing Kong district in ChaingRai province (Figure 1).

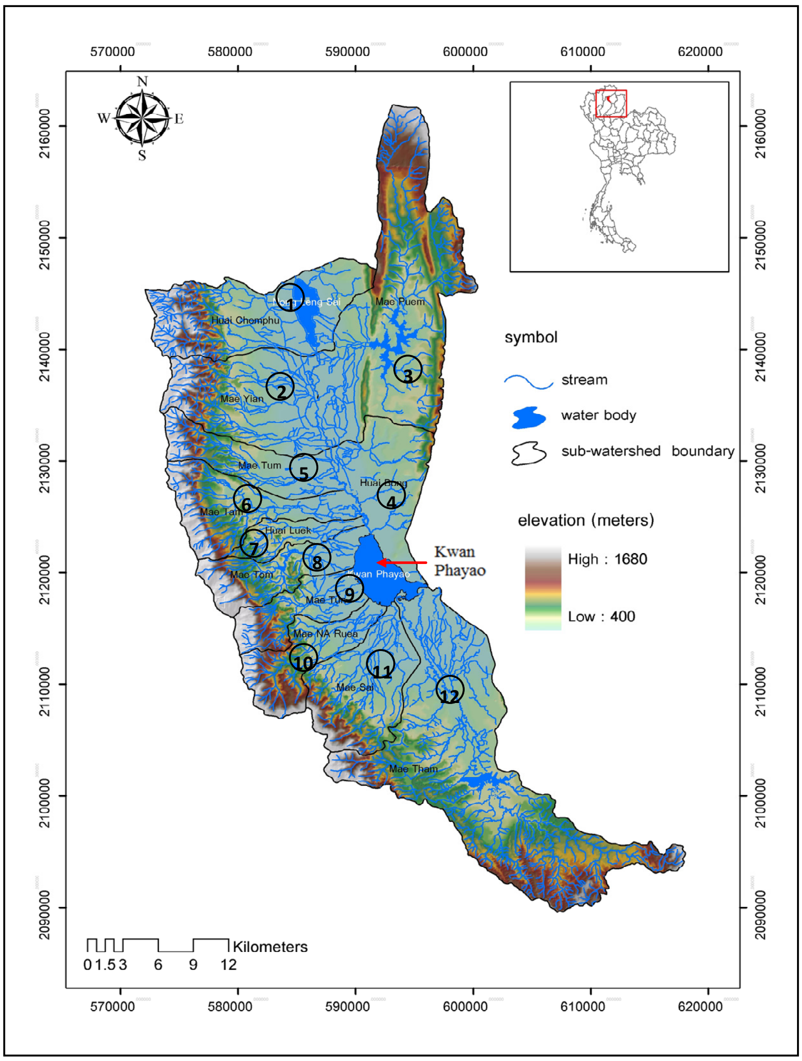



Figure 1. Location of the study area with topography and stream network

## 3. Method

The flowchart summarizes the methodology of the study as shown in Figure 2. Different components of the methods are detailed below:

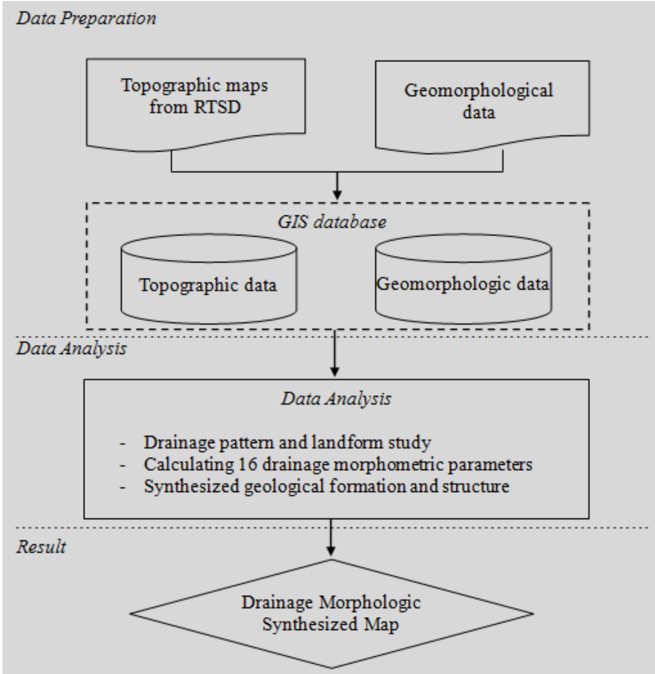



Figure 2. Methodology for synthesizing drainage morphology

*3.1 Data Preparation*

The based map of upper Ing watershed based on the Royal Thai Survey Department (RTSD) topographic maps on a 1:50,000 scale was prepared and imported to Geographic Information System (GIS) software-ArcGIS 9.3 platform. This software has been used for digitization and computational purpose and also for output generation.

*3.2 Data Analysis*

*1) Geomorphological Study*

To study the geomorphological structure of tectonic watershed including landform and drainage pattern by review literature and field surveying to check the accuracy of geological and topographic maps and compare with the real appearances such as the rock and the fault occured, the posing of the sediment and the drainage stream flowed.

*2) Synthesizing Drainage Morphology*

Calculating the 16 theoretical value of drainage morphometric parameters including (a) linear aspects like stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio (b) areal aspects like drainage density, drainage texture, stream frequency, form factor, elongation ratio, circularity ratio, length of overlandflow and (c) relief aspects like watershed relief, relief ratio, ruggedness number (Table 1) and using GIS for overlay the geologic formation and tectonic structure maps on drainage morphological map in order to determine their influence on drainage patterns.

Table 1. Drainage morphometric parameters

| No. | Aspects | Parameters | Formulae | References |
|---|---|---|---|---|
| 1 | Linear Aspects | Stream Order (U) | Hierarchial rank | Strahler (1964) |
| 2 | | Stream Length (Lu) | Length of the stream | Horton (1945) |
| 3 | | Mean Stream Length (Lsm) | Lsm = Lu/Nu<br>Where, Lsm = mean stream length<br>Lu = total stream length of order ‘u’<br>Nu = total no. of stream segments of order ‘u’ | Strahler (1964) |
| 4 | | Stream Length Ratio (RL) | RL = Lu/(Lu-1)<br>Where, RL = stream length ratio<br>Lu = total stream length of order ‘u’<br>Lu-1 = total stream length of its next lower order | Horton (1945) |
| 5 | | Bifurcation Ratio (Rb) | Rb = Nu/(Nu+1)<br>Where, Rb = bifurcation ratio<br>Nu = total no. of stream segments of order ‘u’<br>Nu+1 = no. of stream segments of next higher order | Schumm (1956) |
| 6 | | Mean Bifurcation Ratio (Rbm) | Rb = average of bifurcation ratios of all orders | Strahler (1957) |
| 7 | Areal Aspects | Drainage Density (Dd) | Dd = Lu/A<br>Where, Dd = drainage density<br>Lu = total stream length of all orders<br>A = area of the basin ($km^2$) | Horton (1932) |
| 8 | | Drainage Texture (Rt) | Rt = Nu/P<br>Where, Rt = drainage texture<br>Nu = total no. of streams of all orders<br>P = perimeter (km) | Horton (1945)<br>Smith (1950) |
| 9 | | Stream Frequency (Fs) | Fs = Nu/A<br>Where, Fs = stream frequency<br>Nu = total no. of streams of all orders<br>A = area of the basin ($km^2$) | Horton (1932) |
| 10 | | Form Factor (Rf) | $Rf = A/Lb^2$<br>Where, Rf = form factor<br>A = area of the basin ($km^2$)<br>$Lb^2$ = square of basin length | Horton (1932) |
| 11 | | Elongation Ratio (Re) | $Re = 2\sqrt{(A/\pi)}/Lb$<br>Where, Re = elongation ratio<br>A = area of the basin ($km^2$)<br>$\pi$ = ‘Pi’ value (3.142817)<br>Lb = basin length | Schumm (1956) |
| 12 | | Circularity Ratio (Rc) | $Rc = 4*\pi*A/P^2$<br>Where, Rc = circularity ratio<br>$\pi$ = ‘Pi’ value (3.142817)<br>A = area of the basin ($km^2$)<br>$P^2$ = square of perimeter (km) | Miller (1953) |
| 13 | | Length of Overland Flow (Lg) | Lg = 1/Dd*2<br>Where, Lg = length of overland flow<br>Dd = drainage density | Horton (1945) |
| 14 | Relief Aspects | Watershed Relief (H) | vertical distance between the lowest and highest points of watershed (highest – lowest) | Schumm (1956) |
| 15 | | Relief Ratio (Rh) | Rh = H/Lb<br>Where, Rh = relief ratio<br>H = watershed relief<br>Lb = basin length | Schumm (1956) |
| 16 | | Ruggedness Number (Rn) | Rn = H*Dd<br>Where, Rn = ruggedness number<br>H = watershed relief<br>Dd = drainage density | Schumm (1956) |

## 4. Result and Discussion

### *4.1 Pattern of Drainage System*

The drainage pattern in the study arearelated withgeological characteristics and thefault directions, which stretched in two directions. The first direction: northwest-southeast in HuaiChomphu sub-watershed①, Mae Yian sub-watershed② and Mae Tum sub-watershed⑤. The second direction: northeast-southwestin Mae Puem sub-watershed③, Mae Tam sub-watershed⑥, Mae Tom sub-watershed⑧, Mae Na Ruea sub-watershed⑩, Mae Sai⑪ and Mae Tham sub-watershed⑫. Thefault directions affected to the stream positions, stream directions and drainage pattern in each sub-watersheds are shown in Figure 3. This result is conformed withTiyapairat and Mahabhum (1990) which reported the streams in Phayao province and Mae Chai district flow along the fault. In addition, Mae Tham sub-watershed which the faults have most diverse directions, as a result, the streams flow in this watershed are diverse as well.

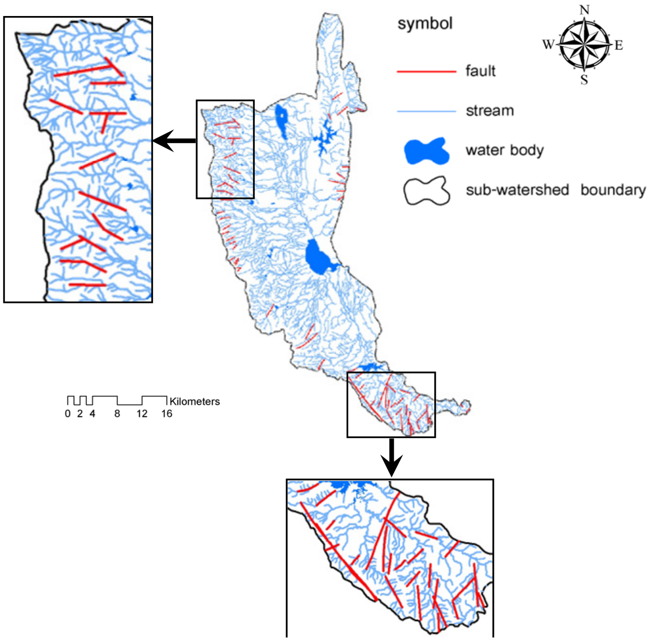



Figure 3. The relationship between streams and fault directions

The most of drainage patterns are dendritic drainage pattern which occur in every sub-watersheds as that shown in Table 2 and Figure 3. This pattern usually form in horizontal sedimentary or in intrusive igneous rocks where the rock mass is reasonably homogeneous, while the rectangular drainage pattern which tributaries confluence angles occurred along cracks and fault directions in northwestern areas in HuaiChomphu①, Mae Yian②, Mae Tum⑤, Mae Tam⑥, and occurred in southern area in Mae Tham sub-watershed⑫. In addition, the trellis drainage pattern which the main streams are directed by the folded structures in syncline structural geology, whereas smaller streams are at work on adjacent slopes, joining the main stream at right angles (Selby, 1985). This drainage pattern occured in northeast areas in Mae Puem sub-watershed③, which drainage patterns are controlled by rock structures of variable resistance, as shown in Table 2 and Figure 4.

Table 2. Drainage pattern of sub-watersheds in upper Ing watershed

| No. | Sub-watersheds | Drainage pattern |
|---|---|---|
| ① | HuaiChomphu | Dendritic, Rectangular |
| ② | Mae Yien | Dendritic, Rectangular |
| ③ | Mae Puem | Dendritic, Trellis |
| ④ | Huai Bong | Dendritic |
| ⑤ | Mae Tum | Dendritic, Rectangular |
| ⑥ | Mae Tam | Dendritic, Rectangular |
| ⑦ | HuaiLuek | Dendritic |
| ⑧ | Mae Tom | Dendritic |
| ⑨ | Mae Tun | Dendritic |
| ⑩ | Mae Na Ruea | Dendritic |
| ⑪ | Mae Sai | Dendritic |
| ⑫ | Mae Tham | Dendritic, Rectangular |

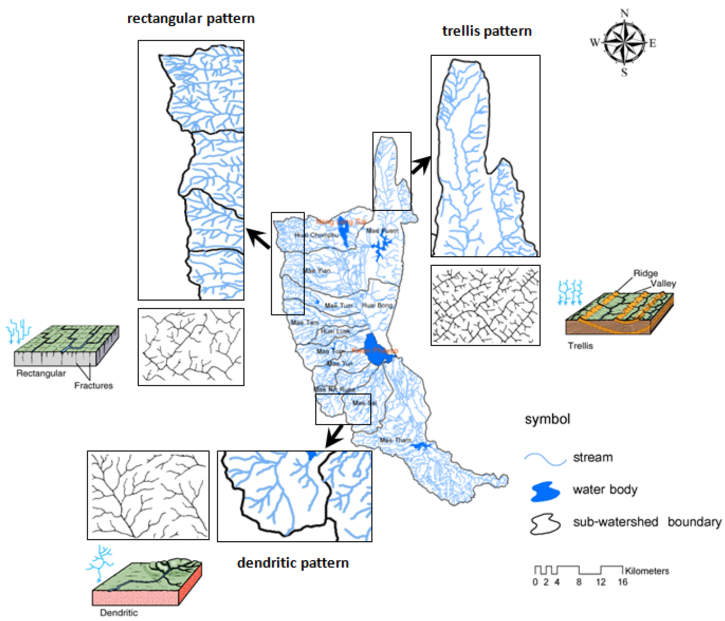



Figure 4. Drainage pattern existing in upper Ing watershed
Source: Adapted some parts from Howard (1967)

*4.2 Drainage Morphology*

*1) Linear Aspect*

*a) Stream Number (Nu)*

The stream orders have been ranked according to Strahler's classification (1964). It was founded that most of the sub-watersheds formed the fourth order including Mae Yian②, Mae Tum⑤, Mae Tam⑥, HuaiLuek⑦, Mae Tom⑧, Mae Tun⑨ and Mae Na Ruea sub-watershed⑩. The sub-watersheds formed the fifth orderincluding HuaiChomphu①, Mae Puem③, Mae Sai⑪andMae Tham sub-watershed⑫, and lastly the sub-watershed are formed the third order was Huai Bong sub-watershed. When considering each order founded that the first order streams are most stream number while the fifth order streams are minimal stream number, as shown in Table 3. The result conformed with Strahler (1964), which described the total number of streams gradually decreases as the stream order increases. Morever, it is also found that Mae Tham sub-watershedhaving high values of first order streams which there is a possibility of sudden flash floods after heavy rainfall in the downstreams (Chitra et al., 2011).

*b) Stream Length (Lu)*

The stream length varies with the stream number in each stream orders that is the total length of stream segments is maximum in first order streams and decreases as the stream order increases (Horton, 1945). The result was founded that Mae Tham sub-watershed have most stream length in each orders, followed by Mae Puem, HuaiChomphu, Mae Yian and Mae Sai sub-watershedrespectively, which as shown in Table 3. This result demonstrated that the first order streams was short and situated in upstream area, conformed with Chitra et al. (2011) which indicated the streams with relatively short lengths are representative of areas with steep slopes and finer texture whereas longer lengths of stream are generally indicative of low gradients (Strahler, 1964).

*c) Mean Stream Length (Lsm)*

Mean Stream Length is inversed with the stream number and the stream length in each stream orders, that is the total stream number and the total length of stream segments which is maximum in first order streams was minimal in mean stream length as shown in Table 3. The result showed that the stream in first order was short line, difference with the next order which is longer than. Strahler (1964) indicated the Lsm is a characteristic property related to the size of drainage network components and its associated surfaces.

*d) Stream Length Ratio (RL)*

Stream length ratio (RL) defined as the ratio of the mean length of the one order to the next lower order of the stream segments (Horton, 1945). The result showed the RL values exhibits an increasing trend from lower order to higher order including Huai Bong, Mae Tum, Mae Tam, Mae Tom, Mae Tun and Mae Na Ruea sub-watershed indicating the mature geomorphic stage. While the RL between streams of different order reveals that there is a variation in Huai Chomphu, Mae Yian, Mae Puem, Huai Luek, Mae Sai and Mae Tham sub-watershed indicating the late young geomorphic stage, as shown in Table 4. This variation might be attributed to variation in slope and topography (Magesh et al., 2012).

*e) Bifurcation Ratio (Rb) and Mean Bifurcation Ratio (Rbm)*

Bifurcation ratio (Rb) defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumm, 1956). Horton (1945) considered the Rb as an index of relief and dissections. The result showed that Mae Tum sub-watershed have the highest Rbm values (4.28), whileMae Sai sub-watershed have the lowest Rbm values (2.94), as shown in Table 4. The result conformed with Strahler (1957) who indicated Rb values characteristically range between 3.0 and 6.0 for watersheds in which the geologic structures do not distort the drainage pattern. The sub-watersheds which high Rb values including Mae Tum, Mae Tam, Mae Tham and Mae Tun sub-watershed expected in regions of steeply dipping rock strata, elongated basins and low but extended peak flow, while rounded basins with low ratio produce a sharp peak (Chitra et al., 2011).

Table 3. Linear aspect characteristics of sub-watersheds in upper Ing watershed (1)

| No. | sub-watershedname | order | Basin Area ($km^2$) | Stream number in order (Nu) | | | | | Stream Length (Lu) (km) | | | | | Mean Stream Length (Lsm) (km) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | I | II | III | IV | V | I | II | III | IV | V | I | II | III | IV | V |
| 1 | HuaiChomphu | 5 | 111.96 | 129 | 26 | 5 | 2 | - | 103.5 | 42.1 | 38.7 | 11.4 | 7.7 | 0.8 | 1.6 | 7.8 | 5.7 | 7.7 |
| 2 | Mae Yian | 4 | 95.74 | 92 | 15 | 5 | 2 | - | 100.9 | 22.0 | 37.7 | 25.1 | - | 1.1 | 1.5 | 7.6 | 12.6 | - |
| 3 | Mae Puem | 5 | 215.83 | 128 | 36 | 5 | 2 | 1 | 129.5 | 47.8 | 27.5 | 11.5 | 38.5 | 1.0 | 1.3 | 5.5 | 5.7 | 38.5 |
| 4 | Huai Bong | 3 | 70.60 | 35 | 7 | 2 | - | - | 40.4 | 20.5 | 13.6 | - | - | 1.2 | 2.9 | 6.8 | - | - |
| 5 | Mae Tum | 4 | 52.87 | 57 | 9 | 2 | 1 | - | 59.2 | 19.5 | 8.1 | 10.8 | - | 1.0 | 2.2 | 4.1 | 10.8 | - |
| 6 | Mae Tam | 4 | 67.68 | 70 | 15 | 5 | 1 | - | 64.2 | 23.5 | 15.6 | 29.4 | - | 0.9 | 1.6 | 3.1 | 29.4 | - |
| 7 | HuaiLuek | 4 | 23.24 | 32 | 10 | 2 | 1 | - | 21.4 | 10.4 | 16.4 | 3.5 | - | 0.7 | 1.0 | 8.2 | 3.5 | - |
| 8 | Mae Tom | 4 | 50.78 | 41 | 12 | 3 | 1 | - | 57.5 | 15.5 | 4.4 | 21.0 | - | 1.4 | 1.3 | 1.5 | 21.0 | - |
| 9 | Mae Tun | 4 | 43.38 | 50 | 13 | 2 | 1 | - | 46.8 | 14.4 | 7.5 | 25.1 | - | 0.9 | 1.1 | 3.8 | 25.1 | - |
| 10 | Mae Na Ruea | 4 | 52.41 | 48 | 16 | 5 | 1 | - | 46.2 | 19.1 | 9.3 | 26.2 | - | 1.0 | 1.2 | 1.9 | 26.2 | - |
| 11 | Mae Sai | 5 | 79.51 | 68 | 18 | 6 | 3 | 1 | 67.1 | 40.7 | 19.7 | 19.2 | 11.9 | 1.0 | 2.3 | 3.3 | 6.4 | 11.9 |
| 12 | Mae Tham | 5 | 267.31 | 290 | 57 | 14 | 4 | 1 | 256.6 | 107.6 | 86.6 | 14.7 | 80.0 | 0.9 | 1.9 | 6.2 | 3.7 | 80.0 |

Table 4. Linear aspect characteristics of sub-watersheds in upper Ing watershed (2)

| No. | sub-watershed name | Basin Length (km) | Perimeter (km) | Stream Length Ratio (RL) | | | | Bifurcation Ratio (Rb) | | | | Mean Bifurcation Ratio (Rbm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | II/I | III/II | IV/III | V/IV | I/II | II/III | III/IV | IV/V | |
| 1 | HuaiChomphu | 19.79 | 54.69 | 0.41 | 0.92 | 0.29 | 0.68 | 4.96 | 5.20 | 2.50 | 2.00 | 3.67 |
| 2 | Mae Yian | 14.96 | 47.87 | 0.22 | 1.71 | 0.67 | - | 6.13 | 3.00 | 2.50 | - | 3.88 |
| 3 | Mae Puem | 31.13 | 91.65 | 0.37 | 0.57 | 0.42 | 3.35 | 3.56 | 7.20 | 2.50 | 2.00 | 3.81 |
| 4 | Huai Bong | 9.14 | 46.02 | 0.51 | 0.66 | - | - | 5.00 | 3.50 | - | - | 4.25 |
| 5 | Mae Tum | 16.83 | 42.53 | 0.33 | 0.42 | 1.33 | - | 6.33 | 4.50 | 2.00 | - | 4.28 |
| 6 | Mae Tam | 17.24 | 46.63 | 0.37 | 0.66 | 1.89 | - | 4.67 | 3.00 | 5.00 | - | 4.22 |
| 7 | HuaiLuek | 12.72 | 30.27 | 0.49 | 1.57 | 0.21 | - | 3.20 | 5.00 | 2.00 | - | 3.40 |
| 8 | Mae Tom | 15.40 | 41.96 | 0.27 | 0.28 | 4.81 | - | 3.42 | 4.00 | 3.00 | - | 3.47 |
| 9 | Mae Tun | 12.23 | 35.88 | 0.31 | 0.52 | 3.34 | - | 3.85 | 6.50 | 2.00 | - | 4.12 |
| 10 | Mae Na Ruea | 14.22 | 41.95 | 0.41 | 0.49 | 2.81 | - | 3.00 | 3.20 | 5.00 | - | 3.73 |
| 11 | Mae Sai | 14.46 | 41.26 | 0.61 | 0.48 | 0.97 | 0.62 | 3.78 | 3.00 | 2.00 | 3.00 | 2.94 |
| 12 | Mae Tham | 34.35 | 119.21 | 0.42 | 0.80 | 0.17 | 5.45 | 5.09 | 4.07 | 3.50 | 4.00 | 4.16 |

*2) Areal Aspect*

*a) Drainage Density (Dd)*

Drainage density (Dd) is defined as the total length of streams of all order per drainage area, this values indicates the closeness of spacing of channels (Horton, 1932). This factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover and runoff intensity index, which the low Dd values occur where basin relief is low while high Dd is favoured where basin relief is high (Strahler, 1964). The result showed that Huai

Luek sub-watershed had the highest Dd value (2.22), while Huai Bong sub-watershedhad the lowest Dd value (1.06), as shown in Table 5. The result indicated whole sub-watersheds had Dd values in moderate level (Dd value between 1-5) (Chunkao, 2008).

*b) Drainage Texture (Rt)*

Drainage texture (Rt) is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). The Rt value depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith, 1950). The result was founded that Mae Tham sub-watershedwas the highest Rt value (3.07), while Huai Bong sub-watershedwas the lowest Rt value (0.96), as shown in Table 5. According to Smith's classification, it could be notified that every sub-watersheds have a course drainage texture (Smith, 1950).

*c) Stream Frequency (Fs)*

Stream frequency (Fs) is the ratio of the total number of stream segments of all the orders in the watershed to the total area of the watershed (Horton, 1932). The result showed that Huai Luek sub-watershed was the highest Fs value (1.94), while Huai Bong sub-watershedwas the lowest Fs value (0.62), as shown in Table 5. The Fs value exhibit positive correlation with the drainage density and related to permeability, infiltration capacity and relief of sub-watershed (Chitra et al., 2011), conformed with the physiographic of Huai Bong sub-watershed which has high relief, highly permeable and dense vegetation .

*d) Form Factor (Rf)*

Form factor (Rf) is defined as the ratio of the watershed area to the square of the watershed length. This factor related to stream flow and shape of watershed (Zende & Nagrajan, 2011). The result indicated thatHuai Bong sub-watershedhad the highest Rf value (0.85), while HuaiLuek sub-watershed was the lowest Rf value (0.19), as shown in Table 5. Corresponded with Magesh et al. (2012), the Rf value should always be less than 0.7854 which the value corresponding to a perfectly circular basin and found that only Huai Bong sub-watershedhad Rf value more than Magesh's value. The elongated watershed with low value of Rf indicates that the watershed will have a flatter peak flow for longer duration (Chitra et al., 2011).

*e) Elongation Ratio (Re)*

Elongation ratio (Re) is the ratio between the diameter of a circle of the same area as the drainage basin and the maximum watershed length (Schumm, 1956). The value of Re generally vary from 0.6 to 1.0 over a wide variety of climate and geologic types, and if Re value close to 1.0 are typical of regions of very low relief (Strahler, 1964). These values can be grouped into four categories namely (a) circle (>0.9), (b) oval (0.9 to 0.8) (c) less elongated (<0.7) and (d) elongated (>0.7). The result from this study showed that Huai Bong sub-watershedwas highestRe value (1.04) indicated a circle shape, the second was Mae Yian sub-watershed (0.74) indicated elongated shape, while Huai Luek sub-watershed had the lowest Re value (0.43) indicated less elongated shape too, as shown in Table 5. Furthermore, Huai Chomphu, Mae Tun, Mae Sai and Mae Yian sub-watershed had Re value between 0.6-0.8, conformed withStrahler (1964) defined where as values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope.

*f) Circularity Ratio (Rc)*

Circularity ratio (Rc) is the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the watershed. Miller (1953) indicated the Rc value range 0.4 to 0.5 which strongly elongated and highly permeable homogenous geologic materials. The result showed that the majority of the sub-watersheds had Rc value < 0.5, indicating elongate shape, while Mae Sai sub-watershed and Mae Yian sub-watershed had Rc value > 0.5, indicating circle shape. In addition, Miller (1953) described Rc is a significant ratio that indicates the dendritic stage of a watershed. The sub-watershed which had low Rc value, including Mae Tham (0.24), Mae Puem (0.32) and Huai Luek (0.32), indicated young geomorphic stage, while the sub-watershed which had high Rc value, including Mae Sai (0.59), Mae Yian (0.53) and Huai Chomphu (0.47), indicated mature geomorphic stage, as shown in Table 5.

*g) Length of Overland Flow (Lg)*

Length of overlandflow (Lg) is defined as the length of the longest drainage path that water takes before it gets concentrated (Horton, 1945). The result was founded that Huai Bong sub-watershed was the highest Lg value (0.47), while Huai Luek and Mae Tun sub-watershed was the lowest Lg value (0.23), which as shown in Table 5. The result indicated by Chitra et al. (2011) that the sub-watershed which was high Lg value, such as Huai Bong, the rainwater had to travel relatively longer distance before getting concentrated into stream channels. This feature difference with the sub-watershed which had low Lg value, such as Mae Tun, the rainwater will enter the stream quickly.

Table 5. Areal aspect characteristics of sub-watersheds in upper Ing watershed

| No. | sub-watershedsname | Drainage Density (Dd) | Drainage Texture (Rt) | Stream Frequency (Fs) | Form Factor (Rf) | Elongation Ratio (Re) | Circularity Ratio (Rc) | Length of overlandflow (Lg) |
|---|---|---|---|---|---|---|---|---|
| 1 | HuaiChomphu | 1.82 | 2.98 | 1.46 | 0.29 | 0.60 | 0.47 | 0.28 |
| 2 | Mae Yian | 1.94 | 2.38 | 1.19 | 0.43 | 0.74 | 0.53 | 0.26 |
| 3 | Mae Puem | 1.18 | 1.88 | 0.80 | 0.22 | 0.53 | 0.32 | 0.42 |
| 4 | Huai Bong | 1.06 | 0.96 | 0.62 | 0.85 | 1.04 | 0.42 | 0.47 |
| 5 | Mae Tum | 1.85 | 1.62 | 1.31 | 0.19 | 0.49 | 0.37 | 0.27 |
| 6 | Mae Tam | 1.96 | 1.95 | 1.34 | 0.23 | 0.54 | 0.39 | 0.26 |
| 7 | HuaiLuek | 2.22 | 1.49 | 1.94 | 0.14 | 0.43 | 0.32 | 0.23 |
| 8 | Mae Tom | 1.94 | 1.36 | 1.12 | 0.21 | 0.52 | 0.36 | 0.26 |
| 9 | Mae Tun | 2.16 | 1.84 | 1.52 | 0.29 | 0.61 | 0.42 | 0.23 |
| 10 | Mae Na Ruea | 1.92 | 1.67 | 1.34 | 0.26 | 0.57 | 0.37 | 0.26 |
| 11 | Mae Sai | 1.99 | 2.33 | 1.21 | 0.38 | 0.70 | 0.59 | 0.25 |
| 12 | Mae Tham | 2.04 | 3.07 | 1.37 | 0.23 | 0.54 | 0.24 | 0.25 |

*3) Relief Aspect*

*a) Watershed Relief (H)*

Watershed relief (H) is the maximum vertical difference between the lowest and the highest point of a watershed. The high relief value indicates the gravity of water flow, low infiltration and high runoff conditions (Magesh et al., 2012). The result showed that the sub-watershed which high H value, including Mae Tun (1.28 km), Mae Tom (1.20 km), and Mae Tam (1.06 km), indicated the gravity of water flow, low infiltration and high run off conditions. Differences with Huai Bong sub-watershed, which low H value (0.28 km), indicated the less gravity of water flow, high infiltration and low runoff conditions, as shown in Table 6.

*b) Relief Ratio (Rh)*

Relief ratio (Rh) is defined as the horizontal distance along the longest dimension of the watershed parallel to the principal drainage line (Schumm, 1956). Rh indicating the overall steepness of a drainage basin and it an indicator of intensity of erosion processes operating on the slope of the watershed (Magesh et al., 2012). The result was founded that the Rh value of each sub-watershed is not different, as shown in Table 6. The sub-watersheds having high Rh values are Mae Tun (0.10) and Mae Na Ruea (0.07), may indicated steep slope and high relief, while the lower values was found at Mae Puem (0.02) and Huai Luek (0.02).

*c) Ruggedness Number (Rn)*

Ruggedness Number (Rn) is defined as the ratio between the watershed relief and the drainage density. If the Rn value is higher, the peak discharge rates are likely to be higher and indicated the watershed is susceptible to erosion (Chitra et al., 2011). The result was founded that the sub-watershed which high Rn values, including Mae Tun (2.77), Mae Tom (2.33), and Mae Tam (2.08) as shown in Table 6, may indicatedthe peak discharge rates are likely to be higher and susceptible to erosion. While Huai Bong sub-watershed which lowest Rn values, may indicated the peak discharge rates are likely to be less and low erosion.

Table 6. Relief aspect characteristics of sub-watersheds in upper Ing watershed

| No. | sub-watershedsname | Watershed Relief (H) (km.) | Relief Ratio (Rh) | Ruggedness Number (Rn) |
|---|---|---|---|---|
| 1 | HuaiChomphu | 1.00 | 0.05 | 1.82 |
| 2 | Mae Yian | 0.86 | 0.06 | 1.67 |
| 3 | Mae Puem | 0.52 | 0.02 | 0.61 |
| 4 | Huai Bong | 0.28 | 0.03 | 0.30 |
| 5 | Mae Tum | 1.00 | 0.06 | 1.84 |
| 6 | Mae Tam | 1.06 | 0.06 | 2.08 |
| 7 | HuaiLuek | 0.28 | 0.02 | 0.62 |
| 8 | Mae Tom | 1.20 | 0.08 | 2.33 |
| 9 | Mae Tun | 1.28 | 0.10 | 2.77 |
| 10 | Mae Na Ruea | 1.02 | 0.07 | 1.96 |
| 11 | Mae Sai | 0.68 | 0.05 | 1.36 |
| 12 | Mae Tham | 0.86 | 0.03 | 1.75 |

### *4.3 Drainage Morphometric Parameters of Drainage Patterns*

The drainage morphometric parameters of the study area can be described as follows:

*1) Dendritic Drainage Pattern*

The dendritic drainage pattern is the most common form of drainage system. There are many contributing streams (analogous to the twigs of a tree), which are then joined together into the tributaries of the main river. They develop where the river channel follows the slope of the terrain (Lambert, 1998).

The dendritic drainage pattern occurs in all sub-watersheds which can be classified into two features. The first was the high-altitude dendritic drainage pattern, which situated in upstream including the most parts of Huai Luek⑦, Mae Tom⑧, Mae Tun⑨, Mae Na Ruea⑩ and Mae Sai sub-watershed⑪. The second was the low-altitude dendritic drainage pattern, which situated in lower terrace and plain including the most parts of Huai Bong sub-watershed④, moreover the dendritic drainage pattern occurred in the lowest area of Mae Tham sub-watersheds⑫.

*a) The High-altitude Dendritic Drainage Pattern*

The result showed that the high-altitude dendritic drainage pattern had stream length ratio values (RL) exhibits an increasing trend from lower order to higher order, which indicated the mature geomorphic stage (Magesh et al., 2012). Bifurcation ratio values (Rb) and mean bifurcation ratio (Rbm) in this area were low, indicated moderate steep slopes which moderated discharge of runoff. The drainage density value (Dd) and stream frequency (Fs) in this area was high, while the drainage texture (Rt) were moderated, implying this area situated in undulating, rolling phase, and upper terrace. In addition, the watershed relief (H) and the ruggedness number (Rn) were relatively high, indicating high discharge of runoff.

The high-altitude dendritic drainage pattern affected by physiographical features of the watershed in undulating, rolling phase and upper terrace, which situated between the western highland and the plain which tectonic forces collapsed along the fault and formed a large graben.

*b) The Low-altitude Dendritic Drainage Pattern*

In the area of the low-altitude dendritic drainage pattern had RL values exhibits an increasing trend from lower order to higher order, which indicated the mature geomorphic stage similarly the high-altitude dendritic drainage pattern.The Rb and Rbm values in this area were high, which indicated less slopes. The Dd, Rt and Fs values in this area was low, implying that this area situated in lower terrace and plain. The low-altitude dendritic drainage pattern, had lowest H and Rn value, indicated the peak discharge rates were likely to be less, high infiltration, low discharge of runoff and lightly erosion processes.In addition, the form factor value (Rf) of this drainage pattern was higher than the others, which indicatedits was a circular watershed. Lastly, the low-altitude dendritic drainage pattern founded in the fifth stream order in some sub-watersheds which the length of a fifth stream order was long because the runoff meandering and branching into several sub-streams before flowing into the Kwan Phayao, this landform occurred in the plains nearby the outlet of watershed in Mae Tham sub-watershed.

*2) Rectangular Drainage Pattern*

The rectangular drainage developed on rocks that are of approximately uniform resistance to erosion, but which have two directions of jointing at approximately right angles (Ritter, 2006).

The rectangular drainage pattern occurs in the high-altitude parts of Huai Chomphu①, Mae Yian②, Mae Tum⑤, Mae Tam⑥ and Mae Tham sub-watersheds⑫, which the faults appeared. The result showed that RL values between streams of different order revealed a variation, which indicating the late young geomorphic stage because this area were varied in slope and topography (Magesh et al., 2012). The Rb and Rbm values in this area were moderated, which expected in regions of steeply dipping rock strata, elongated basins and low but extended peak flow, while rounded basins with low ratio produce a sharp peak (Chitra et al., 2011). The Dd, Rt and Fs values in this area was high, implying this area situated in upper terrace and highland. In addition, the H and Rn values were highly than other drainage pattern, indicating the high discharge of runoff and highly erosion processes and indicated the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (Chitra et al., 2011).

*3) Trellis Drainage Pattern*

The geometry of a trellis drainage system is similar to that of a common garden trellis used to grow vines. As the river flows along a strike valley, smaller tributaries feed into it from the steep slopes on the sides of mountains. These tributaries enter the main river at approximately 90 degree angles, causing a trellis-like appearance of the drainage system and trellis drainage is characteristic of folded mountains (Ritter, 2006).

The trellis drainage pattern occurs in only Mae Puem sub-watershed③, which the rock layers bend or tilt in syncline structural geology. The result showed that RL values exhibits an increasing trend from lower order to higher order, which indicated the mature geomorphic stage. Secondly, the Rb and Rbm values in this area were moderated, indicated high steeply slopes which extended peak flow and high discharge of runoff. The Dd, Rt and Fs values in this area are moderated, implied this area situated in upper terrace and highland. In addition, the H and Rn values are moderated, indicated the moderated discharge of runoff and intermediate erosion processes. The trellis drainage pattern had moderated in the H and Rn values, indicated moderated discharge of runoff as well.

The tectonic forces collapsed the northeast upland into syncline structural geology, which formed the trellis drainage pattern.Furthermore, the form factor (Rf), elongation ratio (Re) and circularity ratio (Rc) are a parameters demonstrated the shapes of watersheds, its not shown the characteristics of drainage patterns, which the relationship between drainage patterns and drainage morphological parameters as shown in the Table 7.

Table 7. Relief aspect characteristics of sub-watersheds in upper Ing watershed

| **Drainage patterns** | **Linear aspects** | **Areal aspects** | | | | | **Relief aspects** | |
|---|---|---|---|---|---|---|---|---|
| | **Rbm** | **Dd** | **Rt** | **Fs** | **Rf** | **Lg** | **H** | **Rn** |
| Dendritic | | | | | | | | |
| - high-altitude | L | H | M | H | M | L | H | H |
| - low-altitude | H | L | L | L | H | H | L | L |
| Rectangular | M | H | H | H | M | L | H | H |
| Trellis | M | M | M | M | M | H | M | M |

Note: H=High value, M=Moderate value, L=Low value

*4.4 Geological Structural Control on Drainage Morphology*

Three distinctive drainage patterns can be synthesized based on the geological formation and structure, they are:

*1) Dendritic Drainage Pattern*

Two distinctive areas of dendritic pattern can be found, the highland and lowland. The high-altitude dendritic drainage pattern including 5 sub-watersheds formed in V-shaped valleys where the rock types are impervious and non-porous. The geological structures of this areas on the upland consisted of granite, shale, sandstone, and on the lowland formed on the terrace and alluvial fan sand, gravel bed and colluvial clay formation, which this feature are described by Figure 5, A.

The high-altitude dendritic drainage pattern have been influenced by sedimentary structure that a stream branches flowed not exactly in the direction that the rocks was hard or horizontal position or a same densed rock textures and the equal slope. The characteristics of such rock's types affected to the texture of the drainage pattern. A dense drainage pattern occurred in shale which has a fine-grained and weaker and less competent than granite and sandstone, then shale is less resistant to erosion than granite and sandstone. While a coarse drainage pattern occurred in granite and sandstone which is more resistant to erosion than shale.

The low-altitude dendritic drainage pattern existed only 1 sub-watershed④. The geological structures of this area consisted of fluvial clay and sand formation, and found swampy clay and peat formation in somewhere. These structures affected to stream meandering in mature geomorphic stage.

The low-altitude dendritic drainage pattern has been influenced by sedimentary structure that is the most common form of drainage system. They develop where the river channel follows the slope of the terrain in areas of uniform rock, with little distortion by folding or faulting, the rivers develop a random branching network similar to a tree. The fluvial clay and sand formation in this lowland area affected a fine drainage pattern and influence a stream meandering and branching into several sub-streams before flowing into the Kwan Phayao wetland. It could be said that the sedimentary structure caused both the high-altitude and the low-altitude dendritic drainage patterns.

*2) Rectangular Drainage Pattern*

The rectangular drainage pattern appears in 5 sub-watersheds formed in V-shaped valleys similarly the high-altitude dendritic drainage pattern, which occurred above the multi-directional fault structures. The geological structures consisted of shale, sandstone, terrace sand and gravel bed formation (Figure 5, B).

One can see that, the tectonic structure caused the rectangular drainage pattern in northwest-west area of the watershed. This drainage pattern occurred in areas of various rocks, with little distortion by folding. The faults and joints are usually less resistant to erosion than the bulk rock, so erosion tends to preferentially open the joints and streams eventually develop along the joints. The result is a stream system in which streams consist mainly of straight line segments with right angle bends and tributaries join larger streams at right angles.

In this area, the properties of such rock's types affected to a dense or coarse drainage pattern. A dense drainage pattern occurred in shale which has a fine-grained texture, while a coarse drainage pattern occurred in sandstone which has a coarse-grained texture. Furthermore, the properties of such sandstone's types also affected to a dense or coarse drainage pattern, that is a dense drainage pattern occurred in older sandstone which has a fine-grained texture, while a coarse drainage pattern occurred in younger sandstone which has a coarse-grained texture. It could be said that the tectonic structure caused the rectangular drainage pattern in this study area

*3) Trellis Drainage Pattern*

The trellis drainage pattern in this study occurs only 1 sub-watershed③ and formed in syncline structure, which occurred in northeastern area. The geological structures of this areas consisted of newer shale in the lower areas and sandstone in the higher area around a collapsed graben. This feature occurred in moderated altitude upland and underlied with bending rocks, as shown in Figure 5, C.

The sedimentary structure folding by tectonic force caused the trellis drainage pattern in northeast area of the watershed. The basin shapes are like round synclines, with the youngest strata exposed in the core. Mae Puem's syncline③ are folds with the sedimentary strata (sandstone) dipping toward the axis of the structure and the youngest strata (shale) exposed in the core. In this area, the sandstone layers will stand out prominently around syncline structure, while the shale layers will appear indented, almost hidden, and beneath in a lower area of syncline structure. Shale is a very fissile rock that will readily fragment, while sandstone is typically made of quartz grains that are moderately to well cemented together and is resistant to normal weathering processes. Thus, the types of drainage pattern do not have influence by the rock's types, but the rock's types determine a dense or coarse drainage pattern in this area. It could be said that the tectonic structure and the sedimentary structure are influenced by tectonic force which consequently caused the trellis drainage pattern.

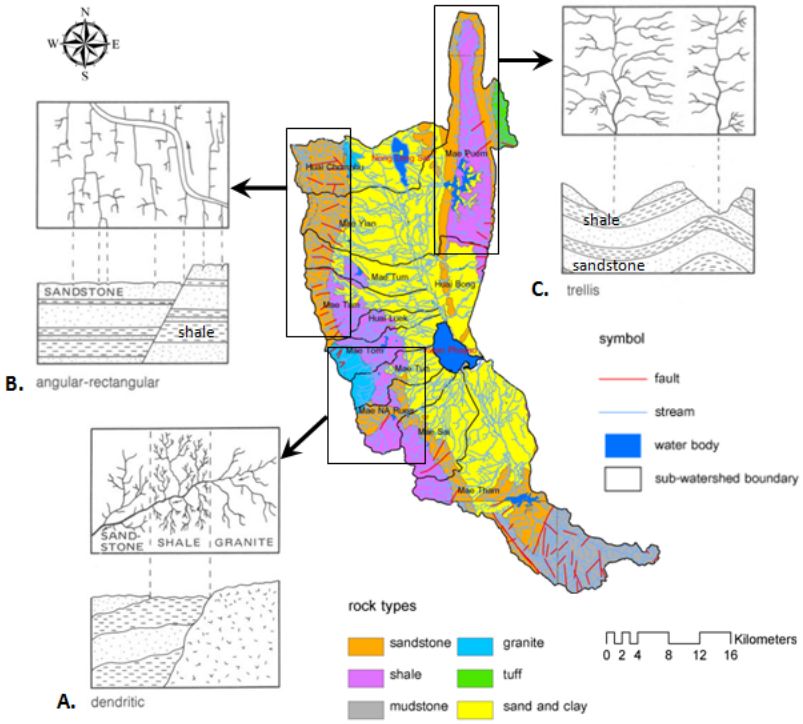



Figure 5. The geological structure of drainage patterns occurred in study area
Source: Adapted some parts from Howard (1967)

Furthermore, the difference of drainage patterns has affected to the power of stream flow. The dendritic drainage pattern which minor streams flowed confluent to major stream in angulary angle. This feature affected stream flow not so severe, less inundation and water spreading not far from the main stream. While the rectangular drainage pattern and the trellis drainage pattern, which minor streams flowed confluent to major stream in right angle. This feature affected stream flow was severe, highly inundation, and water spreading was far from the main stream. However, the difference between rectangular and the trellis drainage pattern were persistence, because the rectangular pattern occurred in the higher altitude than the trellis pattern. Then the gravity of water flow was higher than the trellis pattern, which concluded the rectangular drainage pattern was maximum in stream flow power. These features could be described by Figure 6.

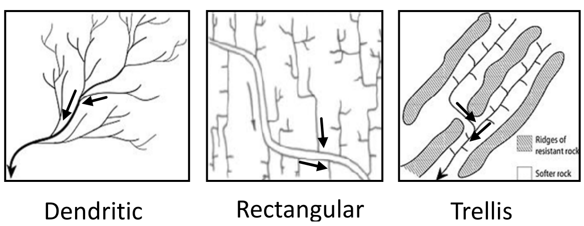



Figure 6. The stream flow direction and power in relation to drainage patterns
Source: Adapted some parts from Howard (1967) and Ritter (2006)

## 5. Conclusion

According to the result of this study, it was demonstrated that the drainage patterns correlated to geological structures and directions of fault. Most of areas were dendritic drainage pattern, which occured in plain, the rectangular drainage pattern was also founded in fault areas, while the trellis drainage pattern occurred in syncline structural geology in northeast area in Mae Puem sub-watershed.

The drainage morphology was analyzed by GIS and calculated 16 parameters in 3 aspects including linear aspect, areal aspect and relief aspect. It was founded that watershed morphology has been controlled by physiography and graben structure. The highland formed in western area and lower to Kwan Phayao which the lowest part of graben, this feature caused the streams runoff more rapidly into the lower areas, affected low permeability and high erosion especially in the western sub-watersheds. On the other hand, the relief aspect of watershed redounded to slow runoff on slopes as well as high permeability and low erosion, which the calculated drainage morphometric parameters showed the result according to their appearances. The result of this study could be applied to watershed management in order to understand the hydrological characteristics of upper Ing involving peak flow of streams, permeable capacity, drainage capacity as well as erosion rate

**Acknowledgement**

The authors wish to thank Professor Dr. Mondhon Sanguansermsri, President of University of Phayao and Professor Dr. Kasem Chunkao, College of Environment, Kasetsart University for supported my doctoral studies. Thanks to Office of the Higher Education Commission, Ministry of Education, Thailand for the doctoral scholarship.

**References**

Chitra, C., Alaguraja, P., Ganeshkumari, K., Yuvaraj, D., & Manivel, M. (2011). Watershed characteristics of Kundahsubbasin using remote sensing and GIS techniques. *International Journal of geomatics and geosciences, 2*(1), 311-335.

Chopra, R. (2005). Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing, 33*(4), 531-539. http://dx.doi.org/10.1007/BF02990738

Chunkao, K. (2008). *Principles of Watershed Management*. Kasetsart University Press, Bangkok. p.341

Horton, R. E. (1932). Drainage basin characteristics. *Transactions of American Geophysics Union, 13*, 350-361.

Horton, R. E. (1945). Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. *Bulletin of Geological Society of America, 56*, 275-370.

Howard, A. D. (1967). Drainage analysis in geologic interpretation. *The American Association of Petroleum Geologists, 51*(11), 2246-2259.

Lambert, D. (1998). *The Field Guide to Geology*. pp. 130-131. Checkmark Books.

Magesh, N. S., Jitheshlal, K. V., & Chandrasekar, N. (2012). GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. *Earth Science Inform, 5*, 111-121. http://dx.doi.org/10.1007/s12145-012-0101-3

Miller, V. C. (1953). *A quantitative geomorphologic study of drainage basin characteristic in the Clinch Mountain area, Virginia and Tennessee*. Project NR 389042, Tech Rep3, Columbia University, Department of Geology, ONR Geography Branch New York.

Narendra, K., & Nageswararao, K. (2006). Morphometry of the meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and resourcesat data. *Journal of the Indian Society of Remote Sensing, 34*(2), 101-110. http://dx.doi.org/10.1007/BF02991815

Office of Natural Resources and Environmental Policy and Planning. (1999). *The Registration of important international and national wetlands in Thailand*. Ministry of Science, Technology and Environment, Bangkok.

Ozdemir, H., & Bird, D. (2009). Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. *Journal of the Indian Society of Remote Sensing, 56*, 1405-1415. http://dx.doi.org/10.1007/s00254-008-1235-y

Ritter, M. E. (2006). *The Physical Environment: an Introduction to Physical Geography*. Retrieved from http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/ title_page.html

Schumm, S. A. (1956). Evaluation of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Bulletin of Geological Society of America, 67*, 597-646.

Selby, M. J. (1985). *Earth's changing surface.* Clarendon Press, Oxford, p. 607.

Smith, K. G. (1950). Standards for grading textures of erosional topography. *American Journal of Science, 248*, 655-668.

Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. *Transactions of American Geophysics Union, 38*, 913-920.

Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel networks. In: Chow V.T. (ed.), *Handbook of Applied Hydrology*. McGraw Hill Book Company, New York.

Thomas, J., Joseph, S., Thrivikramji, K. P., & Abe, G. (2011). Morphometric analysis of the drainage system and its hydrological implications in the rain shadow regions, Kerala, India. *Journal of Geographical Sciences, 21*(6), 1077-1088. http://dx.doi.org/10.1007/s11442-011-0901-2

Tiyapairat, S., & Mahabhum, T. (1990). *Report of Geological Survey and Quaternary Geological Survey in Phayao Province and Mae Chai District*. Geology Division, Department of Mineral Resources, Bangkok.

Vittala, S. S., Govindaiah, S., & Gowda, H. H. (2004). Morphometric analysis of sub-watersheds in the pavagada area of Tumkur district, South India using remote sensing and gis techniques. *Journal of the Indian Society of Remote Sensing, 32*(4), 101-110. http://dx.doi.org/10.1007/BF03030860

Zende, A. M., & Nagrajan, R. (2011). Drainage morphology approach for water resources development of sub watershed in Krishna basin. *International Journal of Computer and Communication Technology, 2*(8), 13-21.

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# Moving Mass and Reaction Compound Control System Design for Reentry Aircrafts

Jun Zhou[1], Xiaoting Wang[1] & Peng Lin[1]

[1] Institute of Precise Guidance and Control, Northwestern Polytechnical University, Xi'an, China

Correspondence: Jun Zhou, Institute of Precise Guidance and Control, Northwestern Polytechnical University, Xi'an 710072, China. E-mail: loperman@yahoo.cn

Received: November 11, 2012 Accepted: December 1, 2012 Online Published: December 9, 2012

doi:10.5539/mas.v7n1p28 URL: http://dx.doi.org/10.5539/mas.v7n1p28

**Abstract**

Moving mass control (MMC) method is of benefit to reentry aircrafts in shape maintenance, energy consume reduction and load capability increase. However, as an aerodynamic manipulating method, MMC partially lacks ability to perform effectively during a whole airspace flight. To achieve reentry aircrafts control system design goal of high performance and low energy cost, we propose a moving mass and reaction compound control system design method in this paper. Firstly, dynamic models are established for a reentry aircraft actuated by moving mass and reaction compound control system, including MMC actuator models. Secondly, moving mass control periodic equivalent torque (MMCPET) is defined, and an optimal torque distribution compound control method based on MMCPET prediction is presented. The optimal object of torque distribution is minimizing difference from MMCPET and control torque command given by virtual controller. Finally, comparison simulations are performed to demonstrate validity of the proposed method. Simulation results show that the proposed compound control is more effective than moving mass control. Also, even if performance of compound control is nearly the same as that of reaction control, thrust impulse requirement of the former is close to 1/5 of the latter.

**Keywords:** compound control, moving mass control (mmc), reaction control, optimal torque distribution

## 1. Introduction

As a special attitude control method for reentry aircrafts, Moving Mass Control (MMC) has distinct advantages from rudder control and reaction control. For example, the servo system of MMC is settled inside the shell, which makes the control performance of MMC more reliable than rudder control. Also, by using all aerodynamic forces acting on the shell to provide control torque, MMC is more effective than rudder control and need less energy cost than reaction control. Unfortunately, as an aerodynamic manipulating method, MMC is not always able to provide high performance attitude control for a whole airspace reentry aircraft.

As we all known, reaction control system (RCS) is able to provide stable control torque in any aerodynamic condition. Therefore, combining moving mass control with reaction control, we can obtain a new control method that will lead to whole airspace high attitude control performance of reentry aircrafts. According to KONG Xue et al. (2009), adjusting static stability by MMC is helpful to improve reaction control performance. However, the effect of MMC torque on attitude control is not focused in her research, nor is to make full use of MMC torque in compound control system design for reducing energy cost.

In this paper, we focus on making full use of MMCS control torque in moving mass and reaction compound control system design, in order to obtain a compound control system that is high performance and low energy cost, and an optimal torque distribution compound control method is proposed.

## 2. Dynamic Models

### *2.1 Compound Control System Collectivity*

Consider an axial symmetry reentry aircraft actuated by both moving mass control system and reaction control system. The former control system includes three one-dimensional movable blocks. Each of them can move along one of body frame axes without any rotation relative to the body frame. As for the latter, twelve pulse-width modulated thrusters compose the reaction control system. Thrusters for pitch and yaw are located in pairs in the nose and tail of the aircraft, while those for roll are located in the middle. All thrusters are configured to allow "coupled" RCS firings (where thrusters on opposite sides of the aircraft fired together), which allows adjusting the aircrafts attitude without affecting the critical accuracy of their trajectories.

Considering that the reentry aircraft is axial symmetry, the compound control system collectivity for only pitch channel is shown in Figure 1. Here, P represents press center, C represents the total mass center, and O represents mass center of the shell, which is the aircraft except for moving mass control system. Let $\boldsymbol{r}_{OA_1}^{\boldsymbol{B}} = [\delta_1 \quad 0 \quad 0]^T, \boldsymbol{r}_{OA_2}^{\boldsymbol{B}} = [l_2 \quad \delta_2 \quad 0]^T, \boldsymbol{r}_{OA_3}^{\boldsymbol{B}} = [l_3 \quad 0 \quad \delta_3]^T$ be separately the position vector of movable blocks with respect to point O written in body frame, where $\delta_i, i = 1,2,3$ are constrained variable coordinates, and $l_2, l_3$ are constant axial offsets. Let $\boldsymbol{R}^{\boldsymbol{B}} = \begin{bmatrix} R_x & R_y & R_z \end{bmatrix}^T$ be aerodynamic force vector written in body frame, $F$ be the reaction thrust, and $L_{pz}$ be the distance between two coupled pitch thrusters.

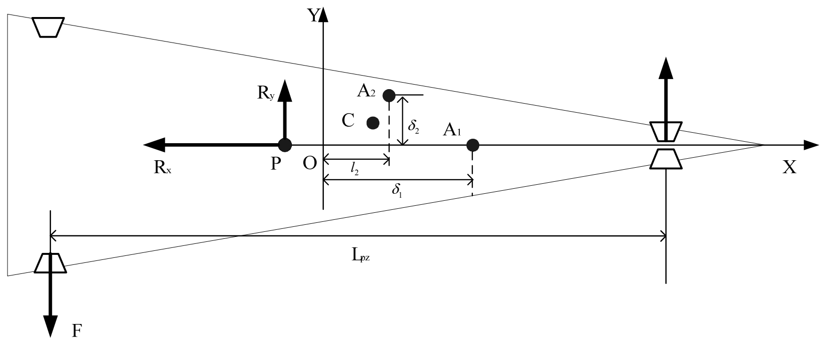



Figure 1. Compound control system collectivity for pitch channel

### *2.2 Govern Equation of Attitude Motion*

Based on angular momentum theorem, vector equation of attitude motion for a reentry aircraft actuated by moving mass and reaction compound control system, which is written in body frame, can be described as

$$\boldsymbol{I_C}\dot{\boldsymbol{\omega}}_{\boldsymbol{O}}^{\boldsymbol{B}} + \boldsymbol{\omega}_{\boldsymbol{O}}^{\boldsymbol{B}} \times \left(\boldsymbol{I_C}\boldsymbol{\omega}_{\boldsymbol{O}}^{\boldsymbol{B}}\right) - \boldsymbol{M}^{\omega}\boldsymbol{\omega}_{\boldsymbol{O}}^{\boldsymbol{B}} = \boldsymbol{R}^{\boldsymbol{B}} \times \boldsymbol{r}_{\boldsymbol{PC}}^{\boldsymbol{B}} + \sum_{j=1}^{12} F_j \boldsymbol{p}_{\boldsymbol{B}_j}^{\boldsymbol{B}} \times \boldsymbol{r}_{\boldsymbol{CB}_j}^{\boldsymbol{B}} - m_s \sum_{i=1}^{3} 2\mu_i \boldsymbol{r}_{\boldsymbol{CA}_i}^{\boldsymbol{B}} \times \left(\boldsymbol{\omega}_{\boldsymbol{O}}^{\boldsymbol{B}} \times \dot{\boldsymbol{r}}_{\boldsymbol{OA}_i}^{\boldsymbol{B}}\right) - m_s \sum_{i=1}^{3} \mu_i \boldsymbol{r}_{\boldsymbol{CA}_i}^{\boldsymbol{B}} \times \ddot{\boldsymbol{r}}_{\boldsymbol{OA}_i}^{\boldsymbol{B}} \quad (1)$$

Where, $\boldsymbol{\omega}_{\boldsymbol{O}}^{\boldsymbol{B}}$ is angular velocity, $\boldsymbol{M}^{\omega} \in R^{3\times 3}$ is aerodynamic damping, $m_s$ is total mass, $\boldsymbol{I_C}$ is inertia and $\boldsymbol{r}_{\boldsymbol{PC}}^{\boldsymbol{B}}$ is the vector from point P to point C. For the ith movable block, $\mu_i$ is the ratio from block mass to total mass, and $\dot{\boldsymbol{r}}_{\boldsymbol{OA}_i}^{\boldsymbol{B}}, \ddot{\boldsymbol{r}}_{\boldsymbol{OA}_i}^{\boldsymbol{B}}$ are block velocity and acceleration with respect to body frame, $\boldsymbol{r}_{\boldsymbol{CA}_i}^{\boldsymbol{B}}$ is the block position vector with respect to point C. For the jth thruster, $F_j$ is the thrust value, $\boldsymbol{p}_{\boldsymbol{B}_j}^{\boldsymbol{B}}$ is the direction vector, and $\boldsymbol{r}_{\boldsymbol{CB}_j}^{\boldsymbol{B}}$ is the vector from point C to the point of thrust.

### *2.3 Actuator Models of MMCS*

The servo characteristic of the movable block can be described as a second order object, therefore motion models of MMCS actuators are

$$\ddot{\delta}_i = -2\xi_i\omega_i\dot{\delta}_i - \omega_i^2\delta_i + \omega_i^2\delta_{ic}, \quad i = 1,2,3 \quad (2)$$

Where, $\delta_{ic}$ is coordinate command of the ith block given by controller, and $\xi_i, \omega_i$ are relative servo damping and nature frequency. Coordinate commands are restricted by space constrains of the blocks.

## 3. Optimal Torque Distribution Compound Control Method

To make up for MMC deficiency, reaction control is introduced to form a compound control method of whole airspace reentry aircrafts. Considering characteristics of those control systems, any good design of the compound control should aim at high performance and low energy cost. One simple design to achieve that goal is dynamically distributing control torque demands given by virtual controller, in the way of making MMC torque as close to torque demands as possible. However, MMC is a continuous control method while reaction control is discrete, which makes the compound system a hybrid system. Consequently, it is difficult to design torque distribution rules without uniform criterion to evaluate control torques provided by MMCS and RCS.

In this paper, we choose periodic equivalent torque to be the uniform torque evaluation criterion, and propose an optimal torque distribution compound control method based on MMC periodic equivalent prediction. Compound control design for only pitch channel is given as an example, and following problems are solved:

- What is MMC periodic equivalent torque (MMCPET) and how to calculate or even predict it;
- What is the optimization function to make full use of MMC torque in the compound control design;

- How to solve the optimal problem and obtain servo commands for both MMCS and RCS.

The structure of proposed compound control is shown in Figure 2.

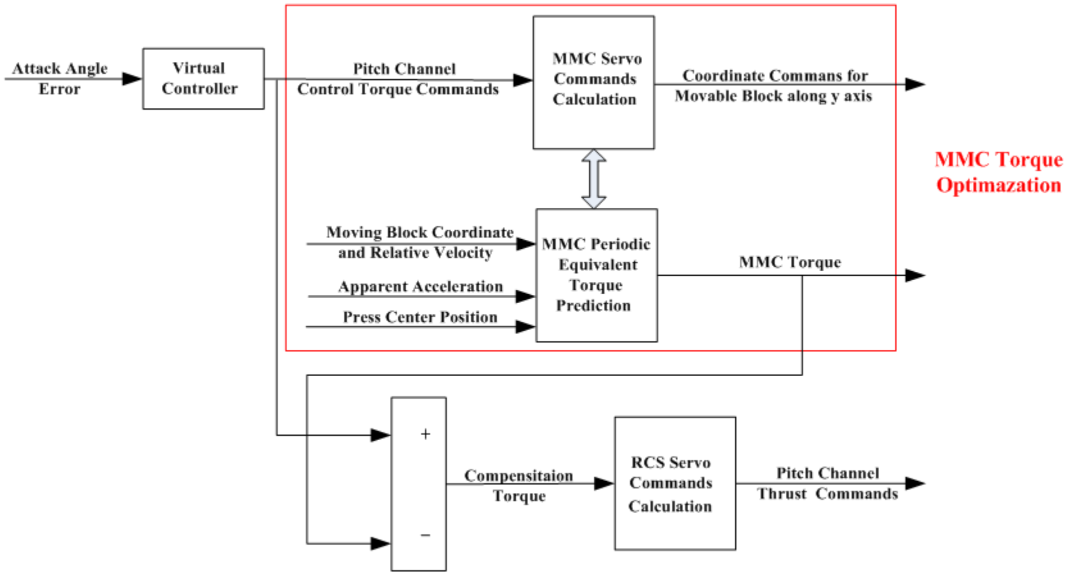



Figure 2. Optimal torque distribution compound control structure

*3.1 Virtual Controller Design*

Suppose lateral motion is indistinctive, attitude motion equations for pitch channel, derived from Equation 1, are

$$\left.\begin{aligned} & I_z\dot{\omega}_z - M_z^{\omega_z}\omega_z = \mu_2\delta_2 R_x - (\mu_1\delta_1 + \mu_2 l_2 + \mu_3 l_3 - l_R)R_y + M_{bz} + f_{z1} \\ & \dot{\alpha} = \omega_z + f_{z2} \end{aligned}\right\} \tag{3}$$

Where, $M_{bz}$ represents RCS periodic equivalent torque with a period of $T_d$, $l_R$ is axial coordinate of press center in body frame, supposed to be a constant.

Let $M_{az} = \mu_2\delta_2 R_x - (\mu_1\delta_1 + \mu_2 l_2 + \mu_3 l_3 - l_R)R_y$ be instantaneous MMC torque, $M_{cz} = M_{az} + M_{bz}$ be compound control torque, and thus the control model for virtual controller design can be obtained according to Equation 3, which is

$$I_z\ddot{\alpha} - M_z^{\omega_z}\dot{\alpha} = M_{cz} + f_z \tag{4}$$

With full consideration of engineering practicability, PID control method is used to design the virtual controller. Therefore the control law is

$$M_{cz} = K_p e_\alpha + K_d \dot{e}_\alpha + K_i \int_0^t e_\alpha dt \tag{5}$$

Where $e_\alpha = \alpha_r - \alpha$ is attack angle error.

*3.2 Definition and Prediction of MMCPET*

We define MMCPET as the average torque of all instantaneous MMC torque working on aircraft during a period of $T_d$, which can be described as

$$M_{ap} = \frac{1}{T_d}\int_0^{T_d}\left[\mu_2\delta_2 R_x - (\mu_1\delta_1 + \mu_2 l_2 + \mu_3 l_3 - l_R)R_y\right]dt \tag{6}$$

Accordingly, only after all aerodynamic forces and MMC block position coordinates during the period are known, MMCPET is able to be calculated. However, to distribute the control torque, what we need is to predict MMCPET in the beginning of every period, and the exact information mentioned above cannot be known. To solve this problem, we use MMCS actuator models to predict MMC block position coordinates during the period, and simplify MMCPET calculation by taking aerodynamic forces as constant values in one period. As a result, the MMCPET prediction method we got is effective when following conditions are satisfied:

- The pulse-width modulation period $T_d$ is short enough that aerodynamic force changes during the period can be neglected reasonably.

- $l_R$ and $\delta_1$ are constants, so as the distance between press center and total mass center $x_{PC} = \mu_1\delta_1 + \mu_2 l_2 + \mu_3 l_3 - l_R$ .
- At the beginning of every period, aircraft apparent acceleration $a_{Ax}, a_{Ay}$ , position coordinate $\delta_{20}$ and relative velocity $\dot{\delta}_{20}$ of the second block can be easily measured on line. Thus the aerodynamic forces at that time can be calculated, and the equations are $R_x = m_s a_{Ax}, R_y = m_s a_{Ay}$ .
- MMCS servo characteristic can be described as Equation 2, and values of $\xi_2, \omega_2$ are known. The space constraint condition of second block is $|\delta_2| \le y_{\max}$

When above conditions are all satisfied, the prediction of MMCPET can be described as

$$\tilde{M}_{ap} = -m_s a_{Ay} x_{PC} + m_s a_{Ax}\mu_2 \left[ \frac{1}{T_d} \int_0^{T_d} \delta_2(t) dt \right] \tag{7}$$

Where, position coordinate prediction $\delta_2(t)$ of the second block during the period is

$$\delta_2(t) = \delta_{2c} - \frac{\dot{\delta}_{20} + \omega_2\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)(\delta_{20} - \delta_{2c})}{2\omega_2\sqrt{\xi_2^2 - 1}\, e^{\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)\omega_2 t}} + \frac{\dot{\delta}_{20} + \omega_2\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)(\delta_{20} - \delta_{2c})}{2\omega_2\sqrt{\xi_2^2 - 1}\, e^{\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)\omega_2 t}}, \quad |\delta_{2c}| \le y_{\max} \tag{8}$$

Equations 7-8 show that MMCPET for one control period is single function of servo command $\delta_{2c}$ , because values of $a_{Ax}, a_{Ay}, \delta_{20}, \dot{\delta}_{20}$ are known constants during the period.

### *3.3 Optimal Torque Distribution Rules and Optimal Solution*

To make full use of MMC torque, we define $J = \left(M_{cz} - \tilde{M}_{ap}\right)^2 / 2$ as our optimal objective function for optimal torque distribution, which can be described as. Let $\delta_{2c}^*$ be the optimal solution of the problem described by

$$\min_{-y_{\max} < \delta_2 < y_{\max}} J \tag{9}$$

And the optimal torque distribution rules are

$$\left.\begin{aligned} M_{ac} &= \tilde{M}_{ap}\left(\delta_{2c}^*\right) \\ M_{bc} &= M_{cz} - \tilde{M}_{ap}\left(\delta_{2c}^*\right) \end{aligned}\right\} \tag{10}$$

Where, the distributive MMC torque $M_{ac}$ equals to the optimal MMCPET $\tilde{M}_{ap}\left(\delta_{2c}^*\right)$, and the distributive reaction control torque $M_{bc}$ is the compensation torque corresponding to the optimal MMCPET.

The above optimal problem is not difficult to be solved. Define two constants to simplify the optimal objective function, which are

$$\left.\begin{aligned} a_\delta &= -m_s a_{Ax}\mu_2 \left[ 1 - \frac{2\xi_2}{\omega_2} - \frac{2\xi_2^2 - 1 - 2\xi_2\sqrt{\xi_2^2 - 1}}{2\omega_2\sqrt{\xi_2^2 - 1}} e^{-\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)\omega_2 T_d} + \frac{2\xi_2^2 - 1 + 2\xi_2\sqrt{\xi_2^2 - 1}}{2\omega_2\sqrt{\xi_2^2 - 1}} e^{-\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)\omega_2 T_d} \right] \\ b_\delta &= M_{cz} + m_s a_{Ay} x_{PC} + m_s a_{Ax}^B \mu_2 \frac{\dot{\delta}_{20} + \delta_{20}\omega_2\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)}{2\omega_2^2\sqrt{\xi_2^2 - 1}\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)} \left[ e^{-\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)\omega_2 T_d} - 1 \right] \\ &\quad + m_s a_{Ax}^B \mu_2 \frac{\dot{\delta}_{20} + \delta_{20}\omega_2\left(\xi_2 + \sqrt{\xi_2^2 - 1}\right)}{2\omega_2^2\sqrt{\xi_2^2 - 1}\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)} \left[ e^{-\left(\xi_2 - \sqrt{\xi_2^2 - 1}\right)\omega_2 T_d} - 1 \right] \end{aligned}\right\} \tag{11}$$

Accordingly, $J$ can be expressed as a quadratic polynomial function of $\delta_{2c}$ , as is shown below

$$J = \left(a_\delta \delta_{2c} + b_\delta\right)^2 / 2 \tag{12}$$

From Equation 12, we can obtain the nonrestraint solution $\delta^* = -b_\delta / a_\delta$ , which satisfies $\left[\partial J / \partial \delta_{2c}\right]_{\delta^*} = 0$ . Define $\boldsymbol{Y_c}$ as the feasible set of the optimal problem, which can be described as $\boldsymbol{Y_c} = \{-y_{\max}, y_{\max}\} \cup \boldsymbol{Y_J}$ . Here, if $-y_{\max} < \delta^* < y_{\max}$ , $\boldsymbol{Y_J} = \{\delta^*\}$, otherwise $\boldsymbol{Y_J} = \varnothing$ . By searching within $\boldsymbol{Y_c}$ , we can easily obtain the optimal solution $\delta_{2c}^*$ .

### *3.4 Servo Commands of MMCS and RCS*

After we solve the optimal torque distribution problem, the distributive torque for MMCS and RCS are obtained. Then we can calculate the servo commands for these two control systems. For MMCS, servo command is position coordinate command of second block. To realize optimal MMCPET, MMC command is chosen to be the optimal solution $\delta_{2c}^{*}$. As for RCS, servo command is actual RCS thrust commands for pitch thrusters. When expected RCS torque $M_{bc}$ is known, RCS thrust commands are able to be calculated by pulse width modulation rules.

## 4. Simulations Results and Analysis

To validate the proposed compound control method, we perform a group of comparison simulations, and the simulation results are shown in Figures 3-5.

With same object, attitude control requirement and virtual controller parameters, performances of compound control method, moving mass control method and reaction control method are compared. In the simulations, MMCS parameters are set to $y_{\max}=0.4, \xi_2=0.707, \omega_2=30$ ; RCS parameters are set to $P_{e1}=1000, P_{e2}=100, T_d=15ms$ ; other parameters are set to $H=30km, V=5000m/s$ . The numerical criterion of high performance is set to be realizing a rising time less than 1 second.

According to simulation results, only MMC is deficiency to realize the expected rising time, and the rising time of compound control is even less than that of reaction control. At the same time, comparing compound control with reaction control, with nearly the same control performance, the thrust impulse requirement ratio from the former to the latter is about 1:5. Therefore, the proposed compound control is better than moving mass control and reaction control, and is able to provide high performance with low energy cost for whole airspace reentry aircrafts.

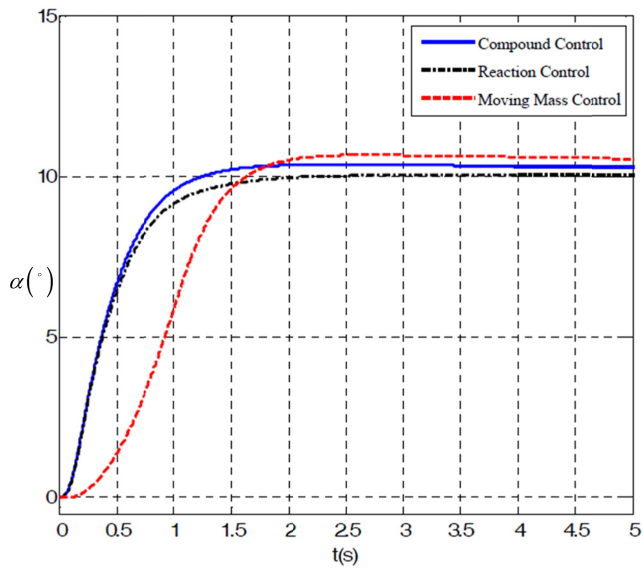



Figure 3. Attack angle response comparison

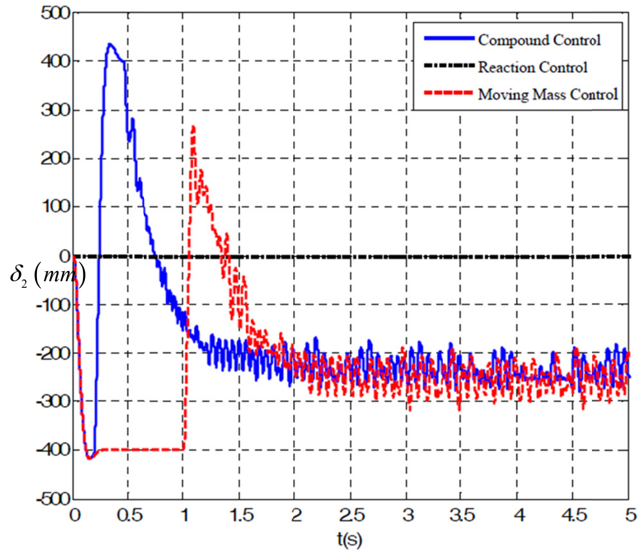



Figure 4. Second movable block coordinate comparison

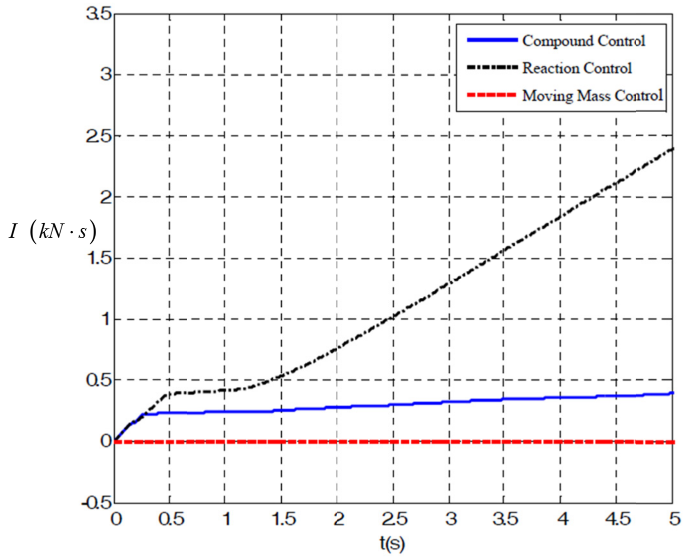



Figure 5. Reaction thrust impulse comparison

## 5. Conclusions

In this paper, we focus on combining moving mass control with reaction control to obtain a compound control for whole airspace reentry aircrafts, in order to achieve control system design target of high performance and low energy cost. An optimal torque distribution compound control system design is proposed and comparison simulation results demonstrate its validity. Moreover, the definition of moving mass control periodic equivalent torque (MMCPET) is the first time put forward, and the optimal torque distribution method based on MMCPET prediction is a helpful exploration to moving mass and reaction compound control system design.


### Acknowledgements

Thanks and gratitude to Institute of Precise Guidance and Control in Northwestern Polytechnical University for the support given in making this study successful.


### References


Guo, Q., Qin, K. Y., & Yang, M. (2010). Integrated guidance and control method of mass moment combined control interceptor. *Journal of Solid Rocket Technology, 33*(4), 363-368.

Kong, X., Yang, M., & Wang, S. Y. (2009). Attitude Control of Mass Torque and Lateral Thrust Combined Control Flight Vehicle. *Computer Simulation, 26*(5), 52-56.

Lin, P., Zhou, F. Q., & Zhou, J. (2007). Moving Centroid Control Mode for Reentry Warhead. *Aerospace Control, 25*(2), 16-20.

Lin, P., Zhou, J., & Zhou, F. Q. (2009). Maneuverability Analysis of Reentry Vehicles Based on Moving Centroid Control Mode. *Aerospace Control, 27*(1), 7-9.

Menon, P. K., Sweriduk, G., Ohlmeyer, E. J., & Malyevac, D. S. (2004). Integrated Guidance and Control of Moving Mass Actuated Kinetic Warheads. *Journal of Guidance Control and Dynamics, 27*(1), 118-126. http://dx.doi.org/10.2514/1.9336

Petsopoulos, T., Regan, F., & Barlow, J. (1996). Moving-Mass Roll Control System for Fixed-Trim Re-Entry Vehicle. *Journal of Spacecraft and Rockets, 33*(1), 54-60. http://dx.doi.org/10.2514/3.55707

Robinett III, R. D., Sturgis, B. R., & Kerr, S. A. (1996). Moving mass trim control for aerospace vehicles. *Journal of Guidance, Control, and Dynamics, 19*(5), 1064-1070. http://dx.doi.org/10.2514/3.21746

Wang, J. S., Xu, S. H., & Liu, H. B. (2006). Design and Simulation of Distribution Strategy of Compound Control in Flying Saucer. *Tactical Missile Technology, 3*, 69-73.

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# The Outcome of Politically Connected Boards on Commercial Bank Performance in Malaysia

Wai-Ching Poon[1], Angeline Kiew-Heong Yap[2] & Teck-Heang Lee[2]

[1] School of Business, Department of Economics, Monash University Sunway Campus, Jalan Lagoon Selatan, Bandar Sunway, Selangor, Malaysia

[2] Department of Business Studies, Help University, Kompleks Pejabat Damansara, Jalan Dungun, Kuala Lumpur, Malaysia

Correspondence: Wai-Ching Poon, School of Business, Department of Economics, Monash University Sunway Campus, Jalan Lagoon Selatan, Bandar Sunway, Selangor 56150, Malaysia. E-mail: Poon.wai.ching@monash.edu

Received: November 2, 2012 Accepted: November 26, 2012 Online Published: December 12, 2012

doi:10.5539/mas.v7n1p35 URL: http://dx.doi.org/10.5539/mas.v7n1p35

**Abstract**

This study draws on upper echelon theory (Hambrick & Mason, 1984) to examine whether the demographic characteristics of politically connected board members affect commercial bank performance in Malaysia. Interaction effect between age, ethnicity, and the political connections of board directors demonstrates that commercial bank performance depends on the presence of non-ethnic minority elder directors who have political connections with higher government authorities. The findings have important implications for corporate governance in commercial banking sectors in Malaysia. Although bank performances are impressive, the valuable human capital resources of board members who have diverse skills and backgrounds remain underutilized. Improving corporate governance performance through better use of human capital resources is of paramount importance for an effective business strategy that facilitates creativity and innovation. Government-Linked Companies (GLCs) should reengineer strategies to support the private sector, instead of crowding out private investment.

**Keywords:** Malaysia, board characteristic, firm performance, politically connected, commercial banks

**JEL Classifications**: L25, M21

## 1. Introduction

The association between the board of directors and firm performance is not easy to explain using a single governance theory (Nicholson & Kiel, 2007) (Note 1). Hambrick and Mason's (1984) upper echelons theory has drawn on the disciplines of organizational behaviour and strategic management. The assertion of upper echelons theory identifies observable demographic characteristics, experiences, values, personalities, or strategic behaviours that influence management's value-added decision making styles, profitability variation and firm performance in response to environmental changes. Using the social identity principle (e.g., attractive-selection-attrition), Tajfel and Turner (1986) and Terjesen et al. (2009) explore how individuals seek to surround themselves in specific groups (so-called "groupthink") who share similar demographic profiles, perceptions and principles, which are then reinforced in intra-group communication. Therefore the portrayer of observable demographic profiles and the compositions of upper echelons (top executives or top management team) are determinants of strategic choices and the firm's performance outcomes (see Bantel & Jackson, 1989; Boeker, 1997).

Diverse human capital (Carter et al., 2010), valuable resources and knowledge of board of directors (Hillman et al., 2000; Jackling & Johl, 2009) affect board performance. Within the context of corporate governance, firms act as a socially cohesive group (Westphal & Zajac, 1995) to channel the human capital (Kresner, 1988) and social capital (Pfeffer & Salancik, 1978) of board directors to facilitate advice, information, legitimacy, communication, and power sharing. Demographic diversity may affect how boards govern their firms, and may influence group decisions. We believe that board diversity increases creativity and innovation, produces a more effective problem-solving approach, enhances the effectiveness of corporate leadership, and promotes more effective global relationships (Carter et al., 2003), and facilitates information exchange, discussion and group performance (Kang et al., 2007). We argue that resource dependency, which focuses on access to resources and preferential treatment, usually shows a positive sign.

Political connections are highly relevant in emerging markets. Malaysia is an appealing setting in this study for various reasons. It is a multi-ethnic and cultural country with concentration of ownership in the hands of a few politically connected Government-Linked Companies (GLCs). Ownership of Public-Listed Companies (PLCs) is identifiable along ethnic lines (Yatim et al., 2006). There are three main indigenous groups in Malaysia, namely Malays (Bumiputras), Chinese, and Indians. As of the 2010 census, the population of Malaysia was 28.3 million, and of that number, 50.4% were Malays, 24.6% were Chinese, 7% were Indians, and the remaining 18% were other natives. Each ethnic group differs economically, culturally and socially. The diverse nature of Malaysian society has become a competitive advantage for many Malaysian firms. The issues of sustainability and inter-generational equity are of great concern in order to achieve the Malaysian government's vision to achieve developed nation status by 2020. We argue that demographic incidents of shareholder activism significantly impact politically connected directors' decisions that ultimately affect commercial bank performance. To what extent demographic diversities of politically connected directors influence the performance of the firm, both observable demographic diversity (e.g., age, ethnicity and qualification) and non-observable cognitive diversity (e.g., education, experience, knowledge, values, perception, affection and personality characteristics), is the focus of our interest.

We have selected commercial banks in this study due to differences in the regulatory requirements by the Bank Negara Malaysia (BNM, the Central Bank of Malaysia). Within the context of the commercial bank industry (Note 2), incidents of shareholder activism by local institutional shareholders often take place. If the government has a direct controlling stake in firm X, this allows them to appoint the Board of Directors (BOD) in firm X. Consequently the politic-based BOD of this firm may react in favour of the objectives of government policy and may distinctively influence the firms' performance. For instance, Employees Provident Funds (EPF, the government agency social security and pension funds), and Permodalan Nasional Berhad (PNB, the government's national capital corporation) held 18.58%[2] direct control of the market in the year 2009 in Malayan Banking Berhad (MBB, the largest local financial group), with EPF: 11.95% and PNB: 6.63% stakes. There were also substantial indirect stake controls of 50.38% by Skim Amanah Saham Bumiputra (ASB, one of the government supported Bumiputra agencies) in MBB. This controlling stake exacerbated the crowding out effect and further aggravated the voting rights of minority investors. It may bring some destructive outcomes in the long term, and threaten moving towards nationalization instead of internationalization. Therefore, a study that focuses on the dark side of political connections, emphasizing over-embeddedness and subjective shareholder expropriation is of value.

Studies of the composition of boards using upper echelon theory in the commercial banking sector have not received much attention. This study sheds light on the performance of commercial banks' by examining the demographic diversity of the politically connected upper echelon BODs within the "groupthink". We use a fixed effect panel approach from 2000-2009 and test a lag effect on firm performance that is uncommon in past studies. Results reveal a positive association between age, size of ethnic minority, qualification (the observable demographic diversity), and experience (the non-observable cognitive diversity) of the politically connected directors on firm performance. Interaction effects show that performance gains are greater for elder politically connected non-ethnic minority directors. This paper shows that the independence of politically connected directors on decision making has been compromised. The contribution of this study is to expand the relationship between political connectedness of the governance structures among Malaysian firms, their upper echelons characteristics, and firm performance to address the corporate governance challenges as important drivers for decision making in the context of multi-ethnicity and cultural emerging economy.

The remainder of this study is organized as follows. The second section provides the applicable theories and hypotheses on the relation between board diversity and performance of the firm. The third section discusses the research methodology, sample, data and variables, followed by a section on model specification. The fourth section discusses the results. Finally, limitations are identified, and implication and concluding remarks in section 5.

## 2. Literature Review

### *2.1 Politically Connected Directors*

A politically connected firm could be a group of large shareholders, such as the CEO, president, vice president, chairman or secretary, who control at least 10 percent of voting share, and are connected with a politician, party, minister, or Parliament member (Faccio, 2006). The extant literature documents an association between politically connected firms and Malay ownership corporations (Faccio, 2006; Fraser et al., 2006; Gomez & Jomo, 2002; Gul, 2006; Johnson & Mitton, 2003), but opinions about the link between political connections and firm performance have been mixed. Some studies found a positive and significant relationship i) between Malaysian firm leverage and political patronage (e.g., Fraser et al., 2006), and ii) between politically connected firms and firm performance (e.g., Fisman, 2001); while others form a different conclusion (e.g., Fan et al., 2007; Chizema & Kim, 2010).

Empirical evidence has proved that a bank with politically connected high-ranking officials enrich the business conditions by permeating many barriers (Baum et al., 2008). Politically connected firms receive preferential treatment from government in the form of cheaper sources of funding, favourable tax treatment and access to restricted licenses (Mohamad et al., 2007; Niessen & Ruenzi, 2010). Since the implementation of New Economic Policy in 1970, the non-Bumiputra businessmen have actively solicited and developed ties with politicians or other special interest groups to influence the allocation of financing (Johnson & Mitton, 2003) and to extract rents from government (Olson, 1982). Banks with affiliated political entity connections may obtain a licence to carry out transactions for governmental bodies and public authorities at rents set below-market-rate loans. Politically well-connected firms enjoy insider governmental informational advantage and find it relatively easier to win tenders for privatization projects and handling rights for the transactions of governmental institutions that likely increase the profitability of the connectedness firms (Faccio, 2006; Fisman, 2001; Roberts, 1990). Therefore, we hypothesize that:

*Hypothesis 1: Having a higher percentage of politically connected directors on board is positively related to bank performance, all else being constant.*

Johnson and Mitton (2003) found capital control in September 1998 primarily benefited firms with strong ties to the Malaysian Former Prime Minister. Furthermore, some evidence has suggested that politically connected firms were more likely to be rescued from financial turmoil than non-connected peers (Johnson & Mitton, 2003; Faccio, 2006). However there were adverse effects on politically connected firms at the early stage of the financial crisis when government cut the subsidies (Johnson & Mitton, 2003). Furthermore, Mitchell and Joseph (2010) also found that politically connected financial firms performed poorer after the removal of capital controls. The firms of politically connected directors performed poorly due to low financial transparency (Bushman et al., 2004), low professionalism and weak governance (Fan et al., 2007), and incompetent operation as the result of cronyism (Gul, 2006). These findings imply that politically connected firms have a higher probability of receiving government bailouts (Faccio et al., 2006). Therefore, we posit that:

*Hypothesis 2: Firms that have had high levels of political-connectedness over the later five years performed poorer than the previous years, all else being constant.*

### *2.2 Age of Directors*

The age and tenure of the directors "may determine his or her effectiveness in managing the firms" (Cornett et al., 2008, p.360). Alderfer (1986) argues that top board members with little experience may limit the effectiveness of firm, as it takes time to gain an in-depth knowledge of the firm and suggests that the more senior (or the longer the tenure of) the directors, the more likely their knowledge of the industry enhance firm performance. Age diversity of board members may be considered from various perspectives. Kang et al. (2007) believe that young board members are more energetic and are therefore more likely to aim for a successful future; middle board members are suitable to hold important positions in companies because they have the ability to integrate new ideas and confidence when making decisions; and senior board members can share their wisdom by giving valuable experience to management and evaluating decisions more accurately. These studies suggest the more senior the board members and the deeper the knowledge of the firms, the better the firm's performance, and hence a senior politically connected director may positively impact firm performance. We also examine the interaction term to test whether bank performance changes for elder politically connected directors. Based on these arguments, we posit that:

*Hypothesis 3: The age of directors is positively related to bank performance, all else being constant.*

*Hypothesis 4: The elderly politically connected directors are positively associated with firm performance, all else being constant.*

### *2.3 Ethnicity of Directors*

Theories from interdisciplinary sources provide a relationship between the ethnic board diversity and firm performance. However, the empirical evidence on this link is mixed. Haniffa and Cooke (2002) examine the relationship between board composition, culture and voluntary disclosure in Malaysia and conclude that Malays are less professional and secretive, and more uniform and conservative in providing disclosures, when compared to Chinese. In contrast, Ramasamy et al. (2007) claim that Malay CEOs showed higher corporate social performance than Chinese CEOs. Carter et al. (2010) examines the relationship between ethnic minority directors in a sample of U.S. boards and firm performance using fixed effect single regression equation, and they find evidence of a positive and significant relationship between the number of ethnic minority on board and return-on-asset (ROA), but no significant relationship is found between ethnic minority director and financial performance. Nevertheless, Erhardt et al. (2003) reveal a significant positive relationship between ethnic minority on both ROA and return-on-equity (ROE) for U.S. firms. Carter et al. (2003) also find a positive and significant relationship between ethnic minority directors on the board and Tobin's *Q*. Zahra and Stanton (1988), however, reveal no relationship between ethnic minority on the board and firm performance for U.S. firms. Based on Carter et al.'s (2010) and Adams and Ferreira's (2009) conjectures, we argue that ethnic minorities promote board independence because a board which has a diverse ethnicity background might be a more active board in considering issues that are not considered by a homogeneously composed board. We extend these studies by using an interaction term to examine whether bank performance changes for the elderly, ethnic minority directors with political connections. Therefore, we state the following hypotheses:

*Hypothesis 5: The number of ethnic minority directors on the board is positively associated with bank performance, ceteris paribus.*

*Hypothesis 6: The elderly politically connected ethnic minority directors change firm performance, all else being constant.*

### 2.4 Qualifications of Directors

The *Malaysian Code on Corporate Governance* (MCCG) (Revised, 2007, p.11, Note 3) recommends that all directors should be equipped with talent, proficiency, and know-how to demonstrate the credibility and accountability of the management team and to promote the corporate image (Haniffa & Cooke, 2002). Higher education of top management directors in organizational contexts is positively related to receptivity to innovation, creativity, and better strategic decision making (Bantel, 1993; Becker, 1970). Therefore innovation has become a key firm strategy to gain competitive advantage (Hitt et al., 1996) and the qualifications of directors are positively related to firm performance (Morbey, 1988). This relationship suggests that education level and a diverse functional background are positively related to organizational performance (Bantel, 1993; Haniffa & Cooke, 2002), especially in business-related background such as in Economics, Law, Marketing, Accounting, Management, or Finance. In addition, Gray (1988) and Wallace and Cooke (1990) suggest that higher education level may increase demand for political awareness and corporate accountability. Hence, less qualified directors are possibly less effective than directors with business qualifications (Ferreira, 2009). Drawing on this strand, we put forward the seventh hypothesis:

*Hypothesis 7: The qualification of directors with business backgrounds increases bank performance, all else being constant.*

### 2.5 Experience

The "groupthink" cohort is a group of top managerial teams who have some relevant data in common such as socioeconomic background, employment and industry, societal experience, functional track, and training, and have been imprinted on its members and shaped their values and perceptions. While directors are chosen based on "the old boy" network or "people like us", they may have their own priorities in decision making, but the politically connected directors have to support the agenda politically if the director perceives his adherence to the continued of directorship tenure with a firm. It is generally believed that homogeneous managerial teams, manifested as cohesiveness and insularity, will make strategic decisions quicker than heterogeneous teams (Hambrick & Mason, 1984). Janis (1972), however, argues that homogeneity leads to inferior decision making (cited in Hambrick & Mason, 1984). In a stable environment or routine situation, problem solving is best handled for a homogeneous group, but in a chaotic environment, problem solving is best managed by a heterogeneous group since diversity of skill allows more airing of alternatives (Filley et al., 1976). Therefore, the following hypothesis is posited:

*Hypothesis 8: The degree of peripheral-function experience of directors is positively related to the firm's performance, all else being constant.*

## 3. Sample, Variables and Model

### *3.1 Sample and Variables*

The sample consisted of an unbalanced panel of all post-merged domestic commercial banks in Malaysia from 2000-2009 (Note 4). Data was extracted from the companies' websites, companies' Annual Reports, and Bankscope. Panel data analysis was employed to avoid unobservable heterogeneity problems in empirical analyses.

*Dependent Variable*. We measured *firm performance* using ROE, a commonly used accounting-based measure of firm performance. Following Fich and Shivdasani (2006), we did not use Tobin's *Q* because if financial or liquidity constraints cause some firms to under invest, the potential value of unexploited investments may lead to a high marginal Tobin's *Q*. If underinvestment is pervasive, formulation would erroneously treat a high market-to-book ratio, which indicates good governance. We obtained the data on ROE from Bankscope.

*Explanatory variables.* We define politically connected directors (POL) as the percentage of directors serving as current or former members of a political party, or current or former delegates from the ruling government (Fan et al., 2007; Niessen & Ruenzi, 2010). Alternately POL could be defined as informal ties between Malaysian politicians and firms run by Malay, Chinese and Indian (Gul, 2006). We measured age (AGE) as tenure in years held by directors. Director age captures the level of expertise built up by the top executive regarding the organization (Alderfer, 1986; Cornett et al., 2008). We expected that senior or longer-tenured directors were less likely to adversely affected performance. Ethnic minority (EM) was measured using the percentage of minority directors on the board (i.e., the Chinese and Indian), while qualification (QUA) measures the percentage of directors with qualifications in business backgrounds (i.e. either in Economics, Law, Marketing, Accounting, Management, or Finance). Experience (EXP) measures the percentage of directors who have experience in the banking industry. To allow for the possibility of partial adjustment to changes in other variables, we included a lagged dependent variable in the performance equation. The one-year lagged firm performance [ROE(-1)] was employed as stakeholders use previous year firm performance to estimate future performance. It is expected that higher value creation may lead them to expect satisfaction of their interests (Delgado-Garcia et al., 2010). Following Bhagat and Bolton (2008), we used the lagged-one value of ROE as an instrument in our estimations, but we lost data due to the one-year lag. To measure whether there was an association between age, political-connected directors and firm's performance, an interaction term POL*AGE was tested. To measure whether there was an association between age, ethnic minority and political-connected director on the firm's performance, another interaction term POL*AGE*EM was used. Other interaction terms, such as POL*AGE*EXP and POL*AGE*QUA, were also tested, but results were insignificant (results are not reported here).

*Control variables*. We controlled for firm and director characteristics through firm fixed effects regression methods. The effects of size were controlled for using the natural log of total assets, as it is related to market returns (Fama & French, 1992). We measured firm size using a natural log of the total assets of the firm. We controlled for board size, measured as the natural log of the number of directors elected on the board. Study considering the effect of board size and financial performance has developed contradictory arguments. Past studies have predicted a positive relation between board size and financial performance (e.g. Dalton et al., 1998; Forbes & Milliken, 1999; Jackling & Johl, 2009). Proponents of this view argue that larger boards provide a larger pool of information, and greater depth of intellectual knowledge may improve the quality of strategic decisions that in turn translate into better performance. While larger firms are argued to have better corporate performance, smaller firms are expected to be less controlled in the distribution of firm value (Delgado-Garcia et al., 2010), thus reducing firm performance. Nonetheless, evidence supports the assertion that larger boards encumber communication, coordination and eventually influence the decision-making competencies of the board (Cornett et al., 2008; Jensen, 1993), and smaller boards are more effective monitors than large boards (Yermack, 1996), suggesting that board size is inversely related to performance. Firm performance may drop as firms grow older (Loderer & Waelchli, 2010) and older firms tend to be larger after merger and acquisition; takeover hazards could increase with firm age, while firm size and age are negatively related to takeover hazard (Palepu, 1986). Therefore we controlled for firm age, measured as the number of years since the firm's first incorporation. The fiscal year-end was controlled for using a dummy variable, with a value of 1 for firms with a 31 December fiscal year-end and zero otherwise (Gul, 2006). Most firms in the sample had a December year-end and all commercial banks had been audited by large audit firms.

*3.2 Model Specification*

The empirical specification aims to explain the pace in commercial banks' performance using a wider demographic board characteristic. The regression used for testing was as follows:

$$PERF_{it} = \beta_0 + \beta_1 POL_{it} + \beta_2 AGE_{it} + \beta_3 EM_{it} + \beta_4 QUA_{it} + \beta_5 EXP_{it} + \beta_6 PERF_{it-1} + \beta_7 POL * AGE + \beta_8 POL * AGE * EM + \beta_9 FS_{it} + \beta_{10} BS_{it} + \beta_{11} FA_{it} + \beta_{12} FY_{it} + \varepsilon_{it} \quad (1)$$

where $i$ equals each firm, $t$ equals time, and $\varepsilon_{it}$ is the random error for each observation, which is independent and identically distributed with mean zero and variance $\sigma^2$. $PERF$ is the financial performance of the firm measured by commonly used *ROE* in governance; $POL$ is the percentage of political connected directors in the board; $AGE$ is the average age of the director; $EM$ is a measure of percentage of ethnic minority on board, i.e., total number of Chinese and Indian directors on the board; $QUA$ is the percentage of qualified directors; $PERF_{it-1}$ is the lagged value of *ROE*; $EXP$ is the percentage of directors with prior experience in banking sector; $POL * AGE$ and $POL * AGE * EM$ are two interaction terms; $FS$ is firm size, as the natural logarithm of the total assets; $BS$ is board size, measured as the natural logarithm of the number of directors on the board; $FA$ is firm age, measured as the number of years since its operation; $FY$ is the fiscal year, as a dummy variable of 1 if financial ended 31 December, zero otherwise.

*3.3 Panel Regression Method*

A linear model of Equation (1) was estimated on a pooled data sample from 2000-2009 with a constant using fixed effect model estimation using Eview software. The general panel model is written as follows:

$$PERF_{it} = \mu + \beta X_{it} + \eta_i + v_t + \varepsilon_{it} \qquad i = 1, \dots, 9; \; t = 1, \dots, 10 \quad (2)$$

where $PERF_{it}$ denotes the dependent variable ($ROE_{it}$) for country $i$ at period $t$, $\beta$ is $kX_i$ coefficient vector, and $X_{it}$ is the $i$-th observation on the $k$ number of explanatory variables [$k$=12, see Eq.(1)]. The term $\eta_i$ is the cross-sectional unit residual, and the term $v_t$ is the unobservable time specific residual to account for firm effect and period effect, respectively. The term $\varepsilon_{it}$ is the usual error term after removing individual and period effects. These residuals are components of the error term from Equation (1) where $e_{it} = \eta_i + v_t + \varepsilon_{it}$.

Panel regression offers flexibility in modelling heterogeneity in country-specific behaviour, and temporal changes in the country's macroeconomic condition. Pooling both time series and cross-section data provides more information, greater variation, less collinearity, greater degree of freedom and more efficiency (Gujarati & Porter, 2009). Fixed-effects models are not without their disadvantages. The constant covariates within individuals cannot be measured in this setting. The fixed effects model allows the unobserved firm effects to be correlated with the deterministic variables. If there is a correlation between the fixed effects and the determinants, the random effects model is preferred. The variance component of the dependent variable can be decomposed into:

$$\sigma_y^2 = \sigma_\eta^2 + \sigma_v^2 + \sigma_\varepsilon^2$$

If $\sigma_\eta^2$ and $\sigma_v^2$ are zero, Equation (2) is merely a simple pooled regression (with no firm or period effects). If the firm and period effects are insignificant, both $\eta_i$ and $v_t$ are zero; in this case OLS provides consistent and efficient estimates for both $\mu$ and $\beta$.

## 4. Results and Discussion

*4.1 Descriptive Statistics and Correlation Matrix*

The Malaysian BODs in the commercial banking sector comprised of 6-15 directors, headed by an independent male "chairperson" and included not more than three female directors. The mean age of BOD is 58.99. Table 1 reports descriptive statistics for all variables. The measures of firm performance indicate that the firms were on average financially sound over the 10 years period. The log of return of equity (ROE) is 14.54, which suggests the net income was higher than the book value of total equity of the firm. The average number of ethnic minority directors (EM) on board was 44.89%, with 22.34% being politically connected directors (POL), 63.77% being directors with qualifications (QUA) in business, and 70.76% of the directors having background experience (EXP) in the banking industry over the sample period. For 78% of the sample firms the fiscal year ended on December 31. The log of the total assets of the firms (FS) is 10.83, with a board size (BS) of 2.29. Table 2 provides the bivariate correlation matrix for variables. The correlation coefficients between the measures of performance and board characteristic are within the acceptable ranged from 0.0008 and 0.6492. These coefficients confirm the choice of both deterministic variables and instruments. We found an inverse relationship for the percentages of ethnic minority and ROE.

*4.2 Unit Root Tests*

Augmented Dickey Fuller (ADF) - Fisher chi-square test, PP Fisher, and Breitung t-stat unit root tests were employed to examine stationarity of the series. The results of the unit root test are reported in Table 3. Results reveal that all series are *I(1)* variables, and the unit root test shows that on average pooled data of all variables are stationary at first difference.

Table 1. Summary statistics, annual data (2000-2009)

| **Variable** | **Definitions and Unit of measurement** | **Mean** | **S.D** | **Min** | **Max** |
|---|---|---|---|---|---|
| ROE | The log of total income divided by total equity. | 14.54 | 11.46 | -63.02 | 43.88 |
| POL | Number of political connected directors (%) | 22.34 | 15.74 | 0.00 | 83.33 |
| AGE | Average age of the director = Sum of the ages of all directors divided by the total number of directors (Year) | 58.99 | 4.04 | 50 | 67.30 |
| EM | Total number of minority (Chinese and Indian, i.e., non-Bumiputra) directors on the board (%) | 44.89 | 25.70 | 0.00 | 90.91 |
| QUA | Total number of directors with qualification either in Law, Business and Management, or Economics (%) | 63.77 | 26.36 | 12.50 | 100.00 |
| EXP | Number of directors who have background experience in banking sector (%) | 70.76 | 36.72 | 0 | 100.00 |
| FS | Firm size – The natural log of the total assets of the company. | 10.83 | 0.78 | 9.12 | 12.38 |
| BS | Board size – The natural log of total number of directors on the board. | 2.289 | 0.20 | 1.79 | 2.71 |
| FA | Firm age – The natural log of the number of years since its operation. | 21.80 | 19.45 | 3.77 | 48.55 |
| FY | Fiscal year as indicator variable, 1 for fiscal year ended 31 December; 0 otherwise | 0.778 | 0.42 | 0 | 1.00 |

Table 2. Correlations matrix

| | ROE | AGE | POL | EM | QUA | EXP | FS | BS | FA | FY |
|---|---|---|---|---|---|---|---|---|---|---|
| ROE | 1.0000 | | | | | | | | | |
| AGE | 0.0215 | 1.0000 | | | | | | | | |
| POL | -0.0541 | 0.3794 | 1.0000 | | | | | | | |
| EM | -0.0449 | -0.4017 | 0.0008 | 1.0000 | | | | | | |
| QUA | 0.2478 | 0.0357 | -0.2519 | 0.0608 | 1.0000 | | | | | |
| EXP | 0.2047 | -0.0549 | -0.0638 | 0.1447 | 0.2774 | 1.0000 | | | | |
| FS | 0.1890 | 0.5189 | -0.0196 | -0.3800 | 0.5154 | 0.1606 | 1.0000 | | | |
| BS | 0.0999 | 0.0149 | -0.0364 | -0.0795 | -0.1696 | -0.209 | 0.1381 | 1.0000 | | |
| FA | 0.0702 | 0.0710 | 0.0550 | 0.2199 | 0.6492 | 0.3243 | 0.5181 | -0.2980 | 1.0000 | |
| FY | -0.2306 | 0.2019 | 0.4316 | 0.0800 | -0.3702 | -0.2135 | -0.3123 | -0.1151 | -0.3699 | 1.0000 |

Notes: The table presents pairwise correlation coefficients between variables. Chinese and Indian are ethnic minorities.

Table 3. Results of panel data regression model

| | ADF-Fisher Chi-square | | PP-Fisher | | Breitung t-stat | |
|---|---|---|---|---|---|---|
| | Level Constant with trend | First difference Constant with trend | Level Constant with trend | First difference Constant with trend | Level Constant with trend | First difference Constant with trend |
| **AGE** | 16.302 | 26.891** | 16.932 | 55.69*** | -0.9574 | -1.257 |
| **EM** | 12.054 | 19.75 | 44.843*** | 79.18*** | 0.9741 | -1.788** |
| **QUA** | 8.3521 | 18.52 | 19.611 | 50.53*** | 0.1272 | -2.118** |
| **POL** | 8.8811 | 15.52 | 14.543 | 44.99*** | 2.7084 | -2.347*** |
| **ROE** | 17.974 | 41.213*** | 21.764 | 77.57*** | 0.4224 | -0.299 |
| **ROE(-1)** | 18.007 | 41.808*** | 26.495 | 74.97*** | 0.5382 | -0.165 |
| **EXP** | 8.9240 | 32.49** | 23.662* | 51.67*** | -0.3945 | -1.225 |
| **FS** | 8.248 | 19.416 | 15.108 | 51.52*** | -0.0436 | -2.629*** |
| **BS** | 11.554 | 26.658** | 10.360 | 95.33*** | -1.1116 | -1.5405* |
| **FA** | 18.420*** | 153.39*** | 165.78*** | 151.91*** | 4.323 | -4.933*** |

Notes: AGE is the average age of the director, EM is the total number of minority (Chinese and Indian, i.e., non-Bumiputra) directors on the board (%), QUA is Total number of directors with qualification either in Law, Business and Management, or Economics (%), POL is the number of political connected directors (%), ROE is the natural log of return to equity, EXP is Number of directors who have background experience in banking sector (%), FS is firm size, measured as the natural log of the total assets of the company, BS is board size, measured as the natural log of total number of directors on the board, FA is firm age, measured as the natural log of the number of years since its operation. The null hypothesis is that the series are non-stationary or contains a unit root. The rejection of null hypothesis for ADF test is based on the MacKinnon critical values. Lag length selection is based on automatic selection: SIC. Spectral estimation is based on Barlett Kernel, Bandwidth selection is based on automatic Newey-West. *, **, and *** denote the rejection of the null hypothesis of non-stationary at $p<.10$, $p<.05$, and $p<.01$ significance level. Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

### *4.3 Analysis*

Table 4 reports the fixed effect regression models. The association between firm performance and *POL, AGE, EM, QUA, EXP* is tested in both Model 1 (with no control variable) and Model 2 (with control variable - FS and BS). By adding two interaction terms to Model 1, the interaction effects are tested in Model 3. In Model 4, we include lag-one firm performance to Model 1 to test the past year effect on today's performance. In Model 5, we test all variables in Model 4 plus one interaction term to test the interaction effect between POL*AGE on firm performance. By including the control variables to Model 5, a robustness test is carried out in Model 7. In Model 6, we include two interaction terms to test the effects e.g., POL*AGE*EM on firm performance, and lastly the full model is tested in Model 8 (with control variables and interaction terms). The probability of the F-statistic for the overall regression relationship for all independent variables is at least at $p<.05$, except for Model 7 at $p<0.1$. Overall, results reveal significant and positive signs in the predicted direction for the coefficients for *POL*, *AGE*, *QUA*, and *EXP*. The coefficient for *POL* is positive and significant for all models at $p<.05$, thereby providing support for Hypothesis 1. There is evidence suggesting that a higher percentage of politically connected directors on boards enhance bank performance by 3%, holding all other things constant (see Model 8). Therefore having politically connected directors would be an important aspect of corporate performance. This finding implicitly shows that directors representing investors' interests or non-political professionals might obstruct politicians' agendas.

The study reveals age diversity is significant and positively associated with ROE for four out of eight models. This study reveals that senior directors gain more experience and obtain adequate knowledge in banking industry, and thus are more effective in managing the firm. However, these senior directors are compromised due to their political affiliation. Firms with government-linked and politically connected directors need allies on the board to reinforce their objectives and policies that ultimately lead to better persuasive governance, increase professionalism and more attractive firm performances. This finding suggests that the more senior the firm's director, the greater experience, wisdom and understanding of the banking industry, and the better the firm performance. This finding provides weak evidence to support Hypothesis 3 that the age of directors is positively associated with bank performance. Therefore our result is consistent with the assertion that age diversity increases creativity and problem-solving capability Cornett et al. (2008) and Kang et al. (2007). Senior directors are more conservative in pursuing a firm's strategies and tend to focus on business activities that yield immediate profits in the short term during their service periods, ultimately improving firm performance (see Cox, 1993; Li et al., 2011; Milliken & Martins, 1996).

The results show a positive relationship between performance and the qualifications of directors. This finding supports the belief that top management teams who have qualifications in business-related disciplines such as Marketing, Management, Finance, Law or Economics, improved higher banks performance, and therefore supports Hypothesis 7. These qualified directors chose to increase firm performance to promote corporate image, and demonstrate accountability and credibility within the management team. On the other hand, four out of eight models show that directors with relevant business experience are significantly and positively associated with performance, weakly supporting Hypothesis 8.

Results, however, reveal neither ethnic minority nor past performance significantly impact firm performance. We have no evidence to support the notion that firms with directors predominantly by Chinese and Indian outperform the Bumiputra directors in commercial banking industry. Hence, Hypothesis 5, i.e. the assertion that the number of ethnic minority directors on a board is positively associated with bank performance, is not supported. The nature of the relationship between ethnic minority on the board and firm performance is merely a public policy issue. On the other hand, there is no statistical difference when previous year firm performance is added to Models 4-8. This finding suggests that they are more likely to be under the control of politically connected directors for post-merging banks.

For the control variables, results reveal a positive relationship between performance and firm size at $p<1$. This finding is consistent with the argument that larger firms are expected to perform better because they are able to diversify their risks (Ghosh, 1998). In addition, directors are closely monitored by more analysts and thus they are under more pressure to perform well (Haniffa & Hudaib, 2006). However, there is no evidence to support the assertion that larger boards hinder communication, coordination and eventually the performance of the firm.

The coefficient of the interaction term of *POL*AGE* is negative and significant (e.g., $\beta$=-0.754, $p<.01$ in Model 8). From Equation (1), the significant coefficient of the sum of $\beta_1$ and $\beta_7$ is 2.311 (3.065-0.754), providing evidence that senior political-connected directors enhance firm performance by approximately 2.3% compared to non-connected peers (supporting Hypothesis 4). When the ethnic minority factor is taken into account, the significant coefficient for *POL*AGE*EM* ($\beta$=0.0004, $p<.05$) of -0.7536 [the sum of $\beta_7$ and $\beta_8$, i.e., -0.754+0.0004 suggests that elderly political-connected ethnic minority director reduces firm performance by 0.75% (supporting Hypothesis 6). This result suggests that the market does react to the ethnic minority factor. In other words, expectations about merger-related gains are greater for senior politically connected non-ethnic minority directors.

Table 4. Fixed effect regression estimates of the relationship between firm performance and board characteristic

| **Independent variables** | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** | **Model 6** | **Model 7** | **Model 8** |
|---|---|---|---|---|---|---|---|---|
| POL | 0.0500** | 0.0493*** | 3.4434** | 0.0524*** | 3.5001** | 4.5203** | 1.9474** | 3.065*** |
| | (0.016) | (0.0178) | (1.606) | (0.018) | (1.506) | (1.738) | (0.940) | (1.030) |
| AGE | 3.2180 | 4.4042 | 18.738** | 1.2558 | 17.527* | 21.964** | 8.1065 | 11.073* |
| | (5.700) | (6.153) | (9.083) | (6.097) | (9.196) | (9.923) | (5.892) | (5.772) |
| EM | -0.0206 | -0.0232 | -0.0130 | 0.0007 | 0.0042 | -0.0205 | 0.0180* | -0.0113 |
| | (0.0188) | (0.0196) | (0.025) | (0.023) | (0.022) | (0.031) | (0.009) | (0.015) |
| QUA | 0.0404** | 0.0415** | 0.0461*** | 0.0301 | 0.0357* | 0.0351* | 0.0236** | 0.019* |
| | (0.016) | (0.017) | (0.015) | (0.019) | (0.019) | (0.019) | (0.011) | (0.009) |
| EXP | 0.0070 | 0.0058 | 0.0107 | 0.0129 | 0.0169** | 0.0170** | 0.0140** | 0.0166*** |
| | (0.006) | (0.007) | (0.006) | (0.0083) | (0.008) | (0.008) | (0.006) | (0.005) |
| ROE(-1) | | | | -0.0896 | -0.1338 | -0.0692 | -0.1012 | 0.0341 |
| | | | | (0.1298) | (0.125) | (0.137) | (0.112) | (0..105) |
| POL*AGE | | | -0.8297** | | -0.8427** | -1.1015** | -0.4680** | -0.754*** |
| | | | (0.3960) | | (0.3681) | (0.42897) | (0.2288) | (0.2543) |
| POL*AGE*EM | | | -0.00003 | | | 0.0003 | | 0.0004** |
| | | | (0.0002) | | | (0.0002) | | (0.0001) |
| FS | | -0.7132 | | | | | 0.7449 | 0.7518* |
| | | (1.2189) | | | | | (0.5032) | (0.4313) |
| BS | | 0.2330 | | | | | -0.47318 | -0.7817 |
| | | (1.3383) | | | | | (1.1498) | (1.0392) |
| FA | | | | | | | -1.058*** | -1.162*** |
| | | | | | | | (0.3330) | (0.3317) |
| FY | | | | | | | -1.247*** | -1.814*** |
| | | | | | | | (0.5196) | (0.5817) |
| C | -14.3614 | -11.891 | -78.370** | -7.0096 | -74.034* | -91.509** | -37.945* | -47.646** |
| | (23.07) | (23.962) | (37.02) | (24.66) | (37.607) | (40.36) | (22.587) | (22.198) |
| Cross-section fixed effects | √ | √ | √ | √ | √ | √ | | |
| Period fixed effects | √ | √ | √ | √ | √ | √ | √ | |
| Observations | 78 | 78 | 78 | 69 | 69 | 69 | 66 | 66 |
| Number of cross-sections | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| Sample period | 2000-2009 | 2000-2009 | 2000-2009 | 2001-2009 | 2001-2009 | 2001-2009 | 2001-2009 | 2001-2009 |
| $R^2$ | 0.5005 | 0.5038 | 0.5543 | 0.4823 | 0.5363 | 0.5501 | 0.4137 | 0.3517 |
| Adj.R-squared | 0.3007 | 0.2791 | 0.3525 | 0.2348 | 0.2993 | 0.3048 | 0.1716 | 0.2050 |
| F-statistic | 2.5052*** | 2.2422*** | 2.7472*** | 1.9484** | 2.2633*** | 2.2423*** | 1.7087* | 2.3970** |

Notes: All regressions are estimated using panel least squares. Dependent variable: ROE, the natural log of return to equity. POL is the number of political connected directors (%), AGE is the average age of the director, EM is the total number of minority (Chinese and Indian, i.e., non-Bumiputra) directors on the board (%), QUA is Total number of directors with qualification either in Law, Business and Management, Economics, and etc. (%), EXP is Number of directors who have background experience in banking sector (%), FS is firm size, measured as the natural log of the total assets of the company, BS is board size, measured as the natural log of total number of directors on the board, FA is firm age, measured as the natural log of the number of years since its operation, and FY is the Fiscal year as indicator variable, 1 for fiscal year ended 31 December; 0 otherwise. Probability values are based on a t-statistic for a two-tailed test of significance. The first number of each cell is the regression coefficient and figures in the parentheses are standard errors. $R^2$ is the explanatory power of the regressor. *, ** and *** denotes statistically significance at p<10, p<.05 and p<.01 level, respectively.

To test whether politically connected firms performed poorer in the later five years, we divided the sample periods into early years (2000-2004), and later years (2005-2009). Year 2004 has been chosen as the cut-off year because this was the last year the 4th prime minister held official position in the government. Results in Table 5 reveal that the mean value for low politically connected firms shows significant improvement in performance during the later years; meanwhile the mean value for high politically connected firm is relatively lower during the later five years. Hence, we conclude that firms that are politically connected performed poorer in the later five years, thereby supporting Hypothesis 2. These firms performed poorly due to inefficient operation as a result of cronyism and the changing hand among politicians.

Table 5. Mean estimates between political connection and period

| Connection | Early Years (2000-2004), N=45 | Later Years (2005-2009), N=45 |
|---|---|---|
| Low politically connection, N=25 | 1.5291 | 1.8420 |
| High politically connection, N=65 | 2.2677 | 2.0750 |

Note: Full sample, N=90. If number of politically connected director on board is less than 10 percent, it is classified as low politically connection, and otherwise. F statistics=2.888**, ** denotes significant at 5 percent.

*4.4 Endogeneity Test*

The study of the upper echelons board–performance link is plagued with an endogeneity problem, and this problem may bias the results on firm performance. Instances of firms performing well could be due to the political connectedness of the upper-echelons. It could also be due to reputation that these delegates only chose the better performing firms to work for. That is, if the explanatory variable (X) and the error terms were correlated, the OLS estimate would likely be attributed to the X of some of the variation in the dependent variable that actually comes from the error term. In this paper we deal with this endogeneity problem by examining the issue of whether political connectedness affect firm performance or whether firm performance affects political-connectedness. Therefore, formally testing whether or not these explanatory variables are endogeneous is a matter of pre-requisite. We attempt to control for the possible reverse causality by using a time-lagged approach between politically connectedness and firm performance. Specifically, we use the following simple models to determine whether $x_{ik}$ in the model is endogenous or, more precisely, whether it is correlated with the error term $u_i$, where $x_{ik}$ is a $k$-element row vector whose last element, $x_k$.

$$y_i = x_i \cdot \beta + u_i,\ x_{ik} = z_i \cdot + v_i,\ i = 1, 2, \ldots n$$

First we test if beta is equal to zero (it means that $x_i$ has no predictability to $y_i$), save its residual as the first error term; and then $X_{i,t}$ is regressed on $X_{i,t-1}$, again save its residual as the second error term. Finally we test if the first error term is correlated with the second error term. Results reveal that we cannot reject the hypothesis (coefficient= 0.572, *t*-stat=1.070, P=0.288), which implies that error terms do not correlate to each other. Hence the endogeneity problem has been sorted out.

**5. Discussion, Conclusion and Policy Implication**

This study employs upper echelon theory to examine the impact of governance and demographic characteristics of politically connected board members on firm performance. We investigate the impact of political connections, age, ethnic minority, qualification, and experience of board members on commercial bank performance. Results reveal that bank performance of politically connected firms improves compared to the non-connected peers. Overall, we conclude that having a relatively higher number of politically connected directors, qualified senior directors, and peripheral-function experience of directors on the board will lead to higher bank performance, *ceteris paribus*. Consistent with upper echelon theory, the directors' greater knowledge base, creativity and innovation were a competitive advantage to improve bank performance. Hence, there is a need to legitimise the selection of directors with higher educational qualifications. Furthermore, diverse group dynamics are likely to impact controlling function and minimize potential agency issues (Erhardt et al., 2003). The finding in this study is consistent with the argument by Johnson and Mitton (2003) and Gul (2006). While neither ethnic minority nor past performance significantly impacts firm performance, the interaction effects show that ethnic minority plays a role in determining firm's performance, in which there is a positive association between elder non-ethnic minority politically connected directors and bank performance.

The findings suggest that corporate governance can be improved through better use of the entire aptitude capital of the directors. An interaction term that embraces age, ethnic diversity, and political connections is a good practice and serves as a business strategy for creativity and innovation that could strengthen firm performance. The innovation needed now is not to eliminate the long implanted special connections practices within directors, but we need to delve into how politically connected directors can make a difference to improve firm performance as an injection booster to leap forward onto the next podium of economic growth and position Malaysia to become a high income nation by 2020. The Malaysian government has embraced an entire new paradigm via Economic Transformational Program and New Economic Model, particularly focused on private sector's accessibility to capital to boost and rejuvenate investment, facilitate modern business, encourage competition, and attract foreign direct investment in domestic banking institutions.

The results of this study imply that appropriate human capital for directorship brings positive value-added to boards. Therefore, reengineering GLCs, reenergizing the support to private sector, and creating a competitive domestic economy are of utmost importance. GLCs should engineer socioeconomic change through wealth redistribution, and should not crowd out private investment. Trust is an important element amongst different ethnic groups for fundamental economic network integration. Malaysia's major obstacle is the absence of fairer competition to raise competitiveness within the nation. This lack of fairness has caused difficulty for global foreign investors to invest in the nation. Continuous and significant regulatory framework improvements needs to be embedded into government practice with respect to transparency, non-discrimination, objective-based and performance-based criteria, market-based mechanisms and accountability to reap independence, integrity and soundness of policies and regulations. These informational levels will then be prescribed by mechanisms put in place within the competitive governance and legal environment to ensure rational management decision making processes.

Notwithstanding its contributions, this study has limitations. There are only nine commercial banks in Malaysia in the total population at the time of study, and we have included all nine banks data in this study; this sample remains too small to substantiate claims and may cause firm-specific bias. However the sample is restricted to Malaysian commercial banking industry because other industries have different regulation structures, cultural environments and other factors that may result in different board compositions and firm performances. Future research may undertake gender perspective in multiple directorships to measure firm performance within banking industry. Future study may consider both short- and long-term impact of corporate governance reforms on firm performance.

## References

Adams, R. B., & Ferreira, D. (2009). Women in the boardroom and their impact on governance and performance. *Journal of Financial Economics, 94*, 291-309. http://dx.doi.org/10.1016/j.jfineco.2008.10.007

Alderfer, C. P. (1986). The invisible director on corporate boards. *Harvard Business Review, 64*, 38-52.

Anderson, A., & Gupta, P. P. (2009). A cross-country comparison of corporate governance and firm performance: Do financial structure and the legal system matter? *Journal of Contemporary Accounting and Economics, 5*, 61-79. http://dx.doi.org/10.1016/j.jcae.2009.06.002

Bantel, K. (1993). Strategic clarity in banking: Role of top management-team demography. *Psychological Reports, 3*, 1187-1203. http://dx.doi.org/10.2466/pr0.1993.73.3f.1187

Bantel, K., & Jackson, S. (1989). Top management and innovations in banking: Does the composition of the top team make a difference? *Strategy Management Journal, 10*, 107-124. http://dx.doi.org/10.1002/smj.4250100709

Basel Committee on Banking Supervision. (2005). Enchancing corporate governance for banking organisation. Retrieved from http://www.bis.org/publ/bcbs117.pdf

Basel Committee on Banking Supervision. (2006). *Enchancing corporate governance for banking organisation.* Retrieved from http://www.bis.org/publ/bcbs122.pdf

Baum, C. F., Caglayan, M., Schäfer, D., & Talavera, O. (2008). Political patronage in Ukrainian banking. *The Economics of Transition, 16*, 537-557. http://dx.doi.org/10.1111/j.1468-0351.2008.00331.x

Becker, M. H. (1970). Sociometric location and innovativeness: Reformulation and extension of the diffusion model. *American Sociological Review, 35*, 267-304. http://dx.doi.org/10.2307/2093205

Berger, A. N., & Patti, E. B. (2006). Capital structure and firm performance: A new approach to testing agency theory and an application to the banking industry. *Journal of Banking and Finance, 30*, 1065-1102. http://dx.doi.org/10.1016/j.jbankfin.2005.05.015

Bhagat, S., & Bolton, B. (2008). Corporate governance and firm performance. *Journal of Corporate Finance, 14*, 257-273.

Boeker, W. (1997). Strategic change: The influence of managerial characteristics and organizational growth. *Academy of Management Journal, 40*, 152-170. http://dx.doi.org/10.2307/257024

Bushman, R. M., Piotroski, J. D., & Smith, A. J. (2004). What determines corporate transparency? *Journal of Accounting Research, 42*, 207-252. http://dx.doi.org/10.1111/j.1475-679X.2004.00136.x

Carter, D. A., D'Souza, F., Simkins, B. J., & Simpson, W. G. (2010). The gender and ethnic diversity of US boards and board committees and firm financial performance. *Corporate Governance: An International Review, 18*, 396-414. http://dx.doi.org/10.1111/j.1467-8683.2010.00809.x

Carter, D. A., Simkins, B. J., & Simpson, W. G. (2003). Corporate governance, board diversity and firm value. *The Financial Review, 38*, 33-53. http://dx.doi.org/10.1111/1540-6288.00034

Chizema, A., & Kim, J. (2010). Outside directors on Korean boards: governance and institutions. *Journal of Management Studies, 47*, 109-129. http://dx.doi.org/10.1111/j.1467-6486.2009.00868.x

Chong, B. S., Liu, M. H., & Tan, K. H. (2006). The wealth effect of forced bank mergers and cronyism. *Journal of Banking and Finance, 30*, 3215-3233. http://dx.doi.org/10.1016/j.jbankfin.2005.12.004

Cornett, M. M., Marcus, A. J., & Tehranian, H. (2008). Corporate governance and pay-for-performance: the impact of earnings management. *Journal of Financial Economics, 87*, 357-373. http://dx.doi.org/10.1016/j.jfineco.2007.03.003

Cox, T. H. (1993). *Cultural diversity in organisations: Theory, research and practice.* San Francisco, CA: Berrett-Koehler.

Dalton, D. R., Daily, C., Ellstrand, A. E., & Johnson, J. L. (1998). Meta-analytic reviews of board composition, leadership structure and financial performance. *Strategic Management Journal, 19*, 269-290. http://dx.doi.org/10.1002/(SICI)1097-0266(199803)19:3<269::AID-SMJ950>3.0.CO;2-K

Delgado-Garcia, J. B., de Quevedo-Puente, E., & de la Fuente-Sabate, J. M. (2010). The impact of ownership structure on corporate reputation: Evidence from Spain. *Corporate Governance: An International Review, 18*, 540-556. http://dx.doi.org/10.1111/j.1467-8683.2010.00818.x

Erhardt, N. L., Werbel, J. D., & Shrader, C. B. (2003). Board of director diversity and firm financial performance. *Corporate Governance: An International Review, 11*, 102-111. http://dx.doi.org/10.1111/1467-8683.00011

Faccio, M. (2006). Politically connected firms. *American Economic Review, 96*, 369-386. http://dx.doi.org/10.1257/000282806776157704

Fama, E. R., & French, K. (1992). The cross-section of expected stock returns. *Journal of Finance, 47*, 427-465. http://dx.doi.org/10.1111/j.1540-6261.1992.tb04398.x

Fan, J. P. H., Wong, T. J., & Zhang, T. (2007). Politically connected CEOs, corporate governance and post-IPO performance of China's newly partially privatised firms. *Journal of Financial Economics, 84*, 330-357. http://dx.doi.org/10.1016/j.jfineco.2006.03.008

Ferreira, D. (2009). Chapter 12: Board Diversity. In Anderson, R. and Baker H. K. (Eds.), *Corporate Governance: A Synthesis of Theory, Research, and Practice*, 225-242. John Wiley and Sons. http://personal.lse.ac.uk/FERREIRD/research.htm

Fich, E. M., & Shivdasani, A. (2006). Are busy boards effective monitors?. *The Journal of Finance, LXI*, 689-724. http://dx.doi.org/10.1111/j.1540-6261.2006.00852.x

Filley, A. C., House, R. J., & Kerr, S. (1976). *Managerial Process and Organizational Behavior.* Glenview, Illinois: Scott, Foresman and Company.

Fisman, R. (2001). Estimating the value of political connections. *American Economic Review, 91*, 1095-1102. http://dx.doi.org/10.1257/aer.91.4.1095

Forbes, D. P., & Milliken, F. J. (1999). Cognition and corporate governance: Understanding boards of directors as strategic decision-making groups. *Academy of Management Review, 24*, 489-505.

Fraser, D. R., Zhang, H., & Derashid, C. (2006). Capital structure and political patronage: The case of Malaysia. *Journal of Banking and Finance, 30*, 1291-1308. http://dx.doi.org/10.1016/j.jbankfin.2005.05.008

Ghosh, A. (1998). *Does Accounting base performance really improve following corporate acquisitions*?. Working Paper, Zickling School of Business, Baruch College, New York, USA.

Gomez, E. T., & Jomo, K. S. (2002). *Malaysia's Political Economy: Politics, patronage and profits* (2nd ed.). Cambridge: Cambridge University Press.

Gorton, G., & Schmid, F. (1999). Corporate governance, ownership dispersion and efficiency: empirical evidence from Austrian cooperative banking. *Journal of Corporate Finance, 5*, 119-140. http://dx.doi.org/10.1016/S0929-1199(98)00019-4

Gray, S. J. (1988). Towards a theory of cultural influence on the development of Accounting systems internationally. *Abacus, 24*, 1-15. http://dx.doi.org/10.1111/j.1467-6281.1988.tb00200.x

Gujarati, D. N., & Porter, D. C. (2009). *Basic Econometrics* (5th ed.). New York: The McGraw-Hill Companies Inc.

Gul, F. A. (2006). Auditors' response to political connections and cronyism in Malaysia. *Journal of Accounting Research, 44*, 931-963. http://dx.doi.org/10.1111/j.1475-679X.2006.00220.x

Hambrick, D. C., & Mason, P. A. (1984). Upper echelons: The organization as a reflection of its top managers. *Academy of Management Review, 9*, 193-349.

Haniffa, R. M., & Cooke, T. E. (2002). Culture, corporate governance and disclosure in Malaysian corporations. *Abacus, 38*, 317-349. http://dx.doi.org/10.1111/1467-6281.00112

Haniffa, R. M., & Hudaib, M. (2006). Corporate governance structure and performance of Malaysian listed companies. *Journal of Business Finance and Accounting, 33*, 1034-1062. http://dx.doi.org/10.1111/j.1468-5957.2006.00594.x

Hillman, A. J., Cannella, J. A. A., & Paetzold, R. L. (2000). The resource dependence role of corporate directors: Strategic adaption of board composition in response to environmental change. *Journal of Management Studies, 37*, 235-255. http://dx.doi.org/10.1111/1467-6486.00179

Hitt, M. A., Hoskisson, R. E., Johnson, R. A., & Moesel, D. D. (1996). The market for corporate control and firm innovation. *Academy of Management Journal, 39*, 1084-1119. http://dx.doi.org/10.2307/256993

Jackling, B. J., & Johl, S. (2009). Board structure and firm performance: Evidence from India's top companies. *Corporate Governance: An International Review, 17*, 492-509. http://dx.doi.org/10.1111/j.1467-8683.2009.00760.x

Janis, I. L. (1972). *Victims of Groupthink: A Psychological Study of Foreign-Policy Decisions and Fiascoes.* Boston: Houghton Mifflin Company.

Jensen, M. C. (1993). The modern industrial revolution, exit, and the failure of internal control systems. *Journal of Finance, 48*, 831-880. http://dx.doi.org/10.1111/j.1540-6261.1993.tb04022.x

Johnson, S., & Mitton, T. (2003). Cronyism and capital controls: Evidence from Malaysia. *Journal of Financial Economics, 67*, 351-382. http://dx.doi.org/10.1016/S0304-405X(02)00255-6

Kang, H., Cheng, M., & Gray, S. J. (2007). Corporate governance and board composition: diversity and independence of Australian boards. *Corporate Governance, 15*, 194-207. http://dx.doi.org/10.1111/j.1467-8683.2007.00554.x

Kang, J., & Shivdasani, A. (1999). Alternative mechanisms for corporate governance in Japan: an analysis of independent and bank-affiliated firms. *Pacific-Basin Finance Journal, 7*, 1-22. http://dx.doi.org/10.1016/S0927-538X(98)00020-1

Kato, T., & Long, C. (2006). CEO turnover, firm performance and enterprise reform in China: Evidence from micro data. *Journal of Comparative Economics, 34*, 796-817. http://dx.doi.org/10.1016/j.jce.2006.08.002

Kresner, I. (1988). Directors' characteristics and committee membership: An investigation of type, occupation, tenure, and gender. *Academy of Management Journal, 31*, 66-84. http://dx.doi.org/10.2307/256498

Krivogorsky, V. (2006). Ownership, board structure and performance in Continental Europe. *The International Journal of Accounting, 41*, 176-197. http://dx.doi.org/10.1016/j.intacc.2006.04.002

Lefort, F., & Urzua, F. (2008). Board independence, firm performance and ownership concentration: Evidence from Chile. *Journal of Business Research, 61*, 615-622. http://dx.doi.org/10.1016/j.jbusres.2007.06.036

Li, J., Chu, W. L., Lam, C. K., & Liao, S. (2011). Age diversity and firm performance in an emerging economy: Implications for cross-cultural human resource management. *Human Resource Management, 50*, 247-270. http://dx.doi.org/10.1002/hrm.20416

Lin, X., Zhang, Y., & Zhu, N. (2009). Does bank ownership increase firm value? Evidence from China. *Journal of International Money and Finance, 28*, 720-737. http://dx.doi.org/10.1016/j.jimonfin.2008.12.015

Loderer, C., & Waelchli, U. (2010). *Firm age and performance*. Working paper. University of Bern, Switzerland.

Malaysian Code on Corporate Governance, MCCG (Revised). (2007). Kuala Lumpur: Securities Commission.

Milliken, F., & Martins, L. (1996). Searching for common threats: understanding the multiple effects of diversity in organisational groups. *Academy of Management Review, 21*, 402-433.

Mitchell, H., & Joseph, S. (2010). Changes in Malaysia: Capital controls, prime ministers and political connections. *Pacific-Basin Finance Journal, 18*, 460-476. http://dx.doi.org/10.1016/j.pacfin.2010.05.002

Mohamad, S., Hassan, T., Nasir, A., & Chen, C. M. (2007). Characteristics and performance of politically-linked firms in Malaysia. *The International Journal of Finance, 19*, 4576-4603.

Morbey, G. K. (1988). RandD: Its relationship to company performance. *Journal of Product Innovation Management, 5*, 191-200. http://dx.doi.org/10.1016/0737-6782(88)90022-7

Nicholson, G. J., & Kiel, G. C. (2007). Can directors impact performance? A case-based test of three theories of corporate governance. *Corporate Governance: An International Review, 15*, 585-608. http://dx.doi.org/10.1111/j.1467-8683.2007.00590.x

Niessen, A., & Ruenzi, S. (2010). Political connectedness and firm performance: Evidence from Germany. *German Economic Review, 11*, 441-464. http://dx.doi.org/10.1111/j.1468-0475.2009.00482.x

Olson, M. (1982). *The rise and decline of nations*. New Haven and London: Yale University Press.

Palepu, K. G. (1986). Predicting takeover targets: a methodological and empirical analysis. *Journal of Accounting and Economics, 8*, 3-35. http://dx.doi.org/10.1016/0165-4101(86)90008-X

Pfeffer, J., & Salancik, G. (1978). *The external control of organizations: A resource-Dependence perspective*. New York: Harper and Row.

Poon, W. C. (2008). *Malaysian Economy* (2nd ed.). Selangor, Malaysia: Pearson Education, Prentice Hall.

Price, R., Roman, F. J., & Rountree, B. (2011). The impact of governance reform on performance and transparency. *Journal of Financial Economics, 99*, 76-96. http://dx.doi.org/10.1016/j.jfineco.2010.08.005

Ramasamy, B., Ng, H. L., & Hung, W. T. (2007). Corporate social performance and ethnicity: A comparison between Malay and Chinese chief executives in Malaysia. *International Journal of Cross Cultural Management, 7*, 29-45. http://dx.doi.org/10.1177/1470595807075169

Roberts, B. E. (1990). A dead senator tells no lies: seniority and the distribution of federal benefits. *American Journal of Political Science, 34*, 31-58. http://dx.doi.org/10.2307/2111510

Switzer, L. N. (2007). Corporate governance, Sarbanes-Oxley, and small-cap firm performance. *The Quarterly Review of Economics and Finance, 47*, 651-666. http://dx.doi.org/10.1016/j.qref.2007.08.001

Tajfel, H. and Turner, J.C. (1986). The social identity theory of intergroup behaviour. In Worchel, S. and Austin, W.G. (Eds.), *Psychology of Intergroup Relations*, 7-24. Chicago, IL: Nelson-Hall.

Terjesen, S., Sealy, R., & Singh, V. (2009). Women directors on corporate boards: A review and research agenda. *Corporate Governance: An International Review, 17*, 320-337. http://dx.doi.org/10.1111/j.1467-8683.2009.00742.x

Wallace, R. S., & Cooke, T. E. (1990). The diagnosis and resolution of emerging issues in corporate disclosure practices. *Accounting and Business Research, 20*, 143-151. http://dx.doi.org/10.1080/00014788.1990.9728872

Westphal, J. D., & Zajac, E. (1995). Who shall govern? CEO, board power, demographic similarity and new director selection. *Administrative Science Quarterly, 40*, 60-83. http://dx.doi.org/10.2307/2393700

Yatim, P., Kent, P., & Clarkson, P. (2006). Governance structures, ethnicity and audit fees of Malaysian listed firms. *Managerial Auditing Journal, 21*, 757-782. http://dx.doi.org/10.1108/02686900610680530

Yermack, D. (1996). Higher market valuation of companies with a small board of directors. *Journal of Financial Economics, 40*, 185-211. http://dx.doi.org/10.1016/0304-405X(95)00844-5

Yoshikawa, T., & Phan, P. H. (2003). The performance implications of ownership–driven governance reform. *European Management Journal, 21*, 698-706. http://dx.doi.org/10.1016/j.emj.2003.09.013

Zahra, S. A., & Stanton, W. W. (1988). The implications of board of directors' composition for corporate strategy and performance. *International Journal of Management, 5*, 229-236.

**Notes**

Note 1. Past studies used economic-based theories to investigate the association between board composition and firm performance in general (Anderson & Gupta, 2009; Kato & Long, 2006; Krivogorsky, 2006; Lefort & Urzua, 2008; Price, Roman, & Rountree, 2011; Switzer, 2007; Yoshikawa & Phan, 2003), and between board composition-bank performance in particular (Berger & Patti, 2006; Gorton & Schmid, 1999; Kang & Shivdasani, 1999; Lin, Zhang, & Zhu, 2009).

Note 2. The Asian Financial Crisis caused liquidity and insolvency problems for banking industry following excessive deficient collateral property lending and inattentive exposure to share-based lending, leaving them burdened with high Non-Performing Loans (NPLs). BNM enforced a merging scheme with the objective to enhance shareholder value by reinforcing the efficiency and profitability of the financial institutions *vis-a-vis* to minimize post-integration costs. BNM announced on $29^{th}$ July, 1999 that the existing 55 financial institutions (i.e., 20 commercial banks, 23 finance companies, and 12 merchant banks) were to form six-anchor banking groups by the end of September 1999 (Poon, 2008). These six-anchor banks were nominated by the central bank and their selection was politically driven (Mitchell & Joseph, 2010), and linked to allegations of cronyism (Chong, Liu, & Tan, 2006). Some objections arose pertaining to the composition of the groups. The government responded by giving flexibility to the banking institutions to form their own merger groups and the number of groups rose from six to ten, and the merging exercise deadline was extended till the end of January 2000.

Note 3. The guideline for banking sector was published by Basel Committee (1999; 2006), and it lists the responsibility of BOD on operations and financial soundness of the banks. The independent director requirement was announced in 1998, and 1999 was the first year when such regulations were enforced. During the last decade, the government has introduced significant reforms in corporate governance, including the enactment of the revised *Malaysian Code on Corporate Governance* (MCCG) 2007 as the "Best Practice Guide" to promote transparency and encourage self-regulatory behavior among PLCs. "Best practice" advocates that the board composition should have a majority of independent non-executive directors (MCCG Revised 2007, p.11).

Note 4. There are nine domestic commercial banks in Malaysia in the post-merged era. There are seven firms in 2000, eight firms from 2001-2002, and nine firms from 2003-2009.

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# A Study of Factors Affecting in Increasing or Decreasing of Radon Levels in Buildings of Suwaylih Town

Nabil N. Al-Zubaidy[1] & Abdullah I. Mohammad[2]

[1] Department of Applied Science, Faculty of Engineering Technology, Al-Balqa Applied University, Amman, Jordan

[2] Department of Basic Sciences, AL-Huson University College, AL-Balqa' Applied University, Irbid, Jordan

Correspondence: Nabil N. Al-Zubaidy, Department of Applied Science, Faculty of Engineering Technology, Al-Balqa Applied University, PO Box 15008, Amman, Jordan. Tel: 962-777-865-856. E-mail: Nabilalzubaidy@yahoo.com

Received: November 5, 2012 Accepted: December 7, 2012 Online Published: December 13, 2012

doi:10.5539/mas.v7n1p51 URL: http://dx.doi.org/10.5539/mas.v7n1p51

**Abstract**

This research aimed to study the factors affected in radon levels in buildings of Suwaylih town (altitude about 900 to 1300 above the sea level) as areference to Jordan. The study was started from august, 10, 2012 to October, 10, 2012. Suwaylih Town divided into six districts namely, Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon, Al-Bashaaer districts. About 780 Passive dosimeters containing highly pure CR - 39 were distributed randomly in districts of Suwaylih town.

The indoor dosimeters were collected after three months. The collected detectors were chemically etched using 30% KOH for 9 hours at 70 ± 0.1 °C. An optical microscope was used to measure the nuclear alpha track density on the detectors surfaces.

The research results showed that radon concentration affected by many factors, for example, the average concentration in guest rooms was 83 ± 18 $Bq.m^{-3}$ and 70 ± 14 $Bq.m^{-3}$ in bed rooms, while it was 53 ± 10 $Bq.m^{-3}$ in living rooms. Morever, the concentration was about 97 ± 15 $Bq.m^{-3}$ in rooms without ventilation while the concentration was about 30 ± 10 $Bq.m^{-3}$ at rooms ventilated more than 9 hours daily.

The study also showed the concentration was relatively high 90 ± 18 $Bq.m^{-3}$ in buildings made of stones while concentration was low 47 ± 12 $Bq.m^{-3}$ in the buildings made from blocks. In addition, the concentration was different with increase in age of building, the average were 63 ± 15 $Bq.m^{-3}$, 51 ± 13 $Bq.m^{-3}$ and 39 ± 11 $Bq.m^{-3}$ in more than 25 years, between 10 - 25 years and less than 10 years, respectively. In general the radon concentration in Suwaylih town was found to be about 62 ± 13 $Bq.m^{-3}$.

**Keywords:** factors, radon, radon levels, buildings, suwaylih, Suwaylih town, Jordan

## 1. Introduction

Human exposure since its inception to radiation doses issued by the environment in which they live, these doses are known radiation dose resulting from natural environment, These doses are not significant natural gravity, where the quantities are usually less than the allowable limit. The average radiation dose equivalent exposed most people's natural resources around 2.4 m·Sv/y, with a marked contrast given the disparity of these radiation doses varied considerably from one region to another (Durrani & Badr, 1995).

Radon is the largest contributor to human exposure to natural radiation sources. Radon is a colorless gas, no taste and no smell, monatomic, a noble gas, heavier inert gases, radon density greater than the density of air, soluble in water and degrades its nucleus birth alpha particles and solid radioactive nuclei.

Radon descended from a series of uranium in crustal rocks, so the flow rate of radon varies from one region to another due to the differences in radon concentration from one area to another because of the different soils and rocks in the Earth's crust, which is considered the main source of uranium.

The average concentrations of radon gas inside buildings eight times concentrations outside the buildings in the atmosphere moderate, concentration of radon inside buildings depend on the quality of the rock and soil under construction, type walls and style ventilation. In buildings open ventilated continuing the radon concentration inside buildings comparable to radon concentration in open air, while in closed buildings where the air not renewed constantly, it could reach the radon to dangerous levels.

There are a lot of studies about radon emissiom in the environment of the dwellings. It is possible for one house to have elevated levels of radon while a neighboring one dose not (Bajwa & Virk, 1997; Anastasion & Christofides, 2003; Mohammad & Abumurad, 2008; Al-Zubaidy & Mohammad, 2011)

### *1.1 Radon from Building Material*

Another radon source is building material. Building materials with high uranium/radium concentration can generate continuously random in to atmosphere. Such materials, slag, fly ash, etc., could be used in some locations.

The data indicated that some materials such as aerated concrete with alum shale and phosphor - gypsum from sedimentary ores have significantly higher radium concentration than others and cause enhanced radon concentration indoors. Radon exhalation from building materials has been the subject of many studies (Ismail & Abumurad, 1996; Paredes, Kessler, Landalt, Zimemer, & Paustenbach, 1987).

### *1.2 Radon from Natural Gas*

Like crude oil, natural gas is held in reservoirs of porous and permeable rock, containing small amounts of natural radiation. The radiation emanates from $^{238}U$ and its decay daughters; one of the decay daughters is $^{222}Rn$, which mixes with the natural gas. This means that traces can be found in supplies of coal, oil and natural gas.

Radon is not affected by combustion, and passes through the flame. Occasional studies and measurements of radon in natural gas in many parts of the world show that levels of radon in gas cover awide range, and that some sources contain substantially elevated radon levels (Dixon et al., 2002).

The concentration of radon in natural gas at the production wells is found to vary from undetectable values up to about 40 $kBq/m^3$ (Gesell, Johanson, & Bernhardt, 1977). The NRPB has shown that the radon in natural gas presents no significant health risk to gas consumers.

### *1.3 Radon Measurement Detectors*

Measurement is the only reliable way to determine levels of radon in abuilding, which are left in the building for periods from days to months. Although there are three main types of passive radon detectors, most studies used nuclear track detectors SSNTDs, especially known as CR-39 for more accurate, so we used it too (Durrani & Bull, 1987).

#### 1.3.1 Properties of SSNTDs

These detectors are very durable, pose no great handling problems, and are not fogged by exposure to light or affected by moderate degrees of heating. Their simplicity and durability makes them particularly valuable and their robustness enables them to be used in personal dosimetry, SSNTDs have the extra advantage of retaining their record after readout, and that led to their rapid application in a wide variety of fields. But the initial application of the etched track radon dosimetry was at J. Stefan institute in 1976 (Furlan & Tommasino, 1993). Solid state nuclear track detectors have become an important tool in the investigation of the presence of radon gas, not only in indoor air but also in soil (Jonsson et al., 1995). SSNTDs have more advantage and special characteristics over other tybes of detectors, which include:

1)- Maintaining permanent records of tracks.

2)- Can integrate radon over any length of time (from a few days to one year).

3)- Little or no dependence on environmental conditions such as temperature and humidity.

4)- Passive and integrated detectors.

5)- Easy to construct and use.

6)- Small in size and cheap in price.

7)- Detect alpha but not gamma or beta radiations.

This paper aims to study factors affecting the levels of radon in Suwaylih town (northwest of Amman). Previously conducted many studies on radon in various parts of Jordan, and some of these studies are talking about measurements of radon in the soil, buildibgs and water, and others talk about the influence of radon on public health. In this paper, we talked about radon measurements in the buildings of Suwaylih town and measurements affected by different factors such as nature of using rooms, differences of floors, building materials, building age, buildings locations and passive ventilation periods.

### *1.4 Objectives of the Present Work*

Radon is estimated to cause many thousands of deaths each year. Infact, the Surgeon General (US) has warned that radon is the second leading cause of lung cancer in the united state today. Only smoking causes more lungs cancer deaths. So that if we find any significant radon level, suggestions and recommendations will be made to the concerned government officials to reduce the risk of radon for minimum.

It seemed, therefore that it would be scientifically, socially and economically sensible to amount a nutural study of all types of radiation especially radon gas on a large enough scale to provide sufficient data to satisfy the indoor radon. After detailed discussions, the study attempts to satisfy the following objectives:

1)- To mesure the concentration of indoor radon in Suwaylih town.

2)- To suggest some recommendations to reduce and control the concentration of significant indoor radon if any.

3)- To correlate between the age of building and the radon concentration.

4)- To correlate between the age of building materials and the concentration.

5)- To correlate between floor elevation and the radon concentration.

## 2. Methodology

### *2.1 Suwaylih Town Description*

Suwaylih is a town in the northwest of Amman (capital of Jordan), it is one of the oldest cities of Amman and it is a famous wellspring of water. The Suwaylih town of the most popular areas in Amman and is a link between Amman and other governorates, it is altitude about 900 to 1300 above the sea level. Suwaylih has an area of about 12 $km^2$ and it is residents according to the official census for the year 2007 about (68,952) people. Figure 1 shows a map of Suwaylih town which divided into six districts namely, Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon, Al-Bashaaer districts. Suwaylih town (The study area) is characterized as containing buildings of more floors and these are usually limited to 3 - 4 floors. Most of the buildings materials, like steel, rocks, cement and etc are locally manufactured.

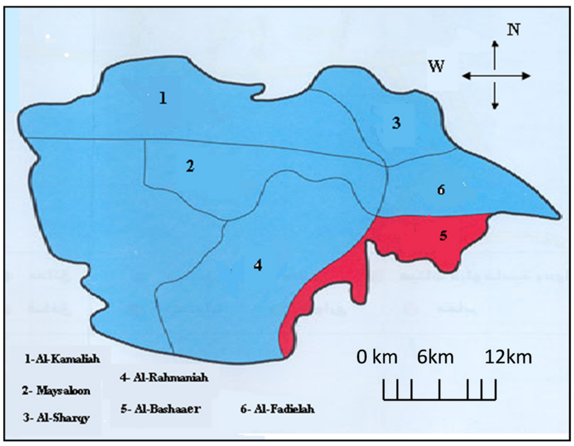



Figure 1. Map of Suwaylih town in Jordan, illustrates its districts

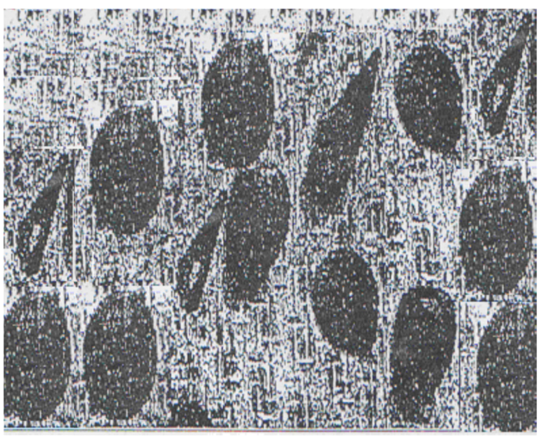


Figure 2. A alpha particle tracks in detector after zoom by optical microscopy

Suwaylih is hot in summer about 30 °C in average, in winter the average temperature drops to about 12 °C and the average rain fall is about 650 ml. The succeeding Amman Silicified Limestone Formation (santonian - campanian) is the youngest bedrock exposed in Suwaylih town. The formation consists of grey and brown, thin to medium - bedded chert, exhibiting a variety of textures ranging from homogeneous to brecciated, interbedded with gery and buff limestone, dolomitic limestone, marl, phosphatic chert, phosphate and apatite schist. These rocks were deposited in asubtidal to shallow shelf environment.

### *2.2 Sample Preparation and Administration*

An integrated passive radon dosimeter has been used for measurement of radon. The dosimeter contain solid state nuclear track detector (SSNTDs) with dimension (1.5 cm × 1.5 cm). The detector has super grade quality of type (CR-39). Adetector fixed on the bottom of can use double face adhesive tape in each dosimeter, the dimension of container 7.0 cm in diameter, 4.6 cm in depth. The container has been covered by lid and was made a cicular hole of diameter 1.5 cm at the center of lid. The hole is covered by a piece of sponge with area of (2 cm ×2 cm) and a thikness of 0.5 cm sealed on to the interior surface of lid.

This configuration was made in order to allow the radon gas to pass through the sponge, while maintain the same calibration condition and to stop the aerosol and thoron ($^{220}$Rn, $t_{½}$ = 55.6 s) from entering the cup.

About 780 dosimeters had been administered in Suwaylih town (each district contain 130 dosimeters). After three months the dosimeters were collected.

### *2.3 Sample Collecting and Etching Condition*

In CR-39, the radiation damage due to alpha particle produces broken molecular chain, free radical and etc. certain chemical reagents (etchants) dissolve or degrade these damage regions at a much higher rate than the undamaged material. The narrow damage trail is thus gouged out by the etchant, forming hole. Having the burrow - like hole in all directions at the lower, bulk etching rate. This etched track may be enlarged radially untill it is visible under an optical microscope. In this context, prior studies have showed that NaOH and KOH are the best solutions to be used with concentration ranging from 1 M to 12 M with tempreture range from 40 to 70 °C and variant etch time (Durrani & Bull, 1987).

All dosimeters had been adminstered in Suwaylih town from August, 10, 2012 to October, 10, 2012. The retrieved detector were chemically etched by using 30% KOH concentration in a water bowl with electric heater for nine hours and temperature was fixed at (70 ± 0.1 °C). Same conditions were applied for calbration dosimeters. After the completion of etching, detectors were washed by distilled water and then dried out.

### *2.4 Counting Background Radiation on CR-39 Surfaces*

To eliminate the effect of background damage on the detector, unused detectors (four detectors from the same plate were chosen randomly and kept in the refrigerator untill the end of the experiment) were etched under the same conditions (30% KOH, 70 °C and 9 hour) and scanned under an optical microscope. The background obtained was very small and less than 3 tracks per view.

### *2.5 Counting Alpha Particles Tracks on CR-39 Surfaces*

For counting the etched tracks, we can use an optical microscope with a magnification power of X10, X40 and some times X100. Then we counted tracks at least 25 different views for radiation resulted from radon decay is purelyrandom phenomenon. After that, the mean and standard deviation of average tracks per view on etch detector were calculated.

In the counting process of the track care must be taken to ditinguish between the tracks and dust prticles. Alpha tracks appear as black holes with different volumes and hape (See Figure 2).

### *2.6 Calibrations*

The calibration process for the dosimeter of this type and dimensions was done in a previous work (Mohammad & Abumurad, 2008) in order to link the obtained track intensity with radon concentration. The radon concentration is calculated by using calculation equations (See Table 1).

Table 1. Relations that have been used to calculate the concentration of radon (Bq.m$^{-3}$) in the air of buildings where, t is exposure time and $\overline{x}$ is the mean

| Lens magnification | Diameter of view area (×10$^{-1}$ cm) | View area ( ×10$^{-2}$ cm$^2$) | Radon concentration |
|---|---|---|---|
| X10 | 1.9 | 2.835 | $C = 349.3\frac{\overline{x}}{t}$ |
| X40 | 0.5 | 0.1963 | $C = 2776.2\frac{\overline{x}}{t}$ |

## 3. Results and Discussion

The present work is study optima to evauate the level of radon in Suwaylih town. Measurements carried out using plastic detectors CR-39, it is hoped that the study will pave for future surveys to establish a Jordanian map of radon emission levels in the different sites (Mohammad & Abumurad, 2008; Al-Zubaidy & Mohammad, 2011, 2012; Al-Zubaidy et al., 2012; Abumurad & Al-Tamimi, 2005).

Radon levels obtained from the above whether as an average or spot measurements needs to be compared with the average national radon level and with the action levels set by different countries and organizations.

This paper was found that the average radon concentration in buildings of Suwaylih town was 62 ± 13 Bq.m$^{-3}$ and this value is far below the action level set by many countries 200 - 600 Bq.m$^{-3}$ (Hudak et al., 1996). After collecting the essential information about places where we put the dosimeters in, we will discuss now factors which may have an effect on the increase or decrease of concentration of radon gas in rooms or buildings.

### *3.1 Nature of Using Rooms*

In this part of study, comparison has been made between radon levels in bedrooms, guest rooms and living rooms located in ground floor buildings. The average concentration in guest rooms was 83 ± 18 Bq.m$^{-3}$ and in bedrooms was 70 ± 14 Bq.m$^{-3}$, while in living rooms the average concentration was 53 ± 10 Bq.m$^{-3}$.

This differences may be due to the long time spent in the living room during the day which need to be in suitable conditions for sitting there, so the ventilation by opening the windows and doors befor longer time than the guest and beed room which usually used during night only and keeping windows closed most of the time to avoid the dust and sometimes because the temperature will decrease in it (See Table 2 & Figure 3).

Table 2. Relation between Radon concentration (Bq.m$^{-3}$) and the natural of room use in ground floor buildings

| Natural of using room | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Guest room | 41 | 43 | 248 | 83 ± 18 |
| Bed room | 38 | 34 | 201 | 70 ± 14 |
| Living room | 37 | 26 | 173 | 53 ± 10 |

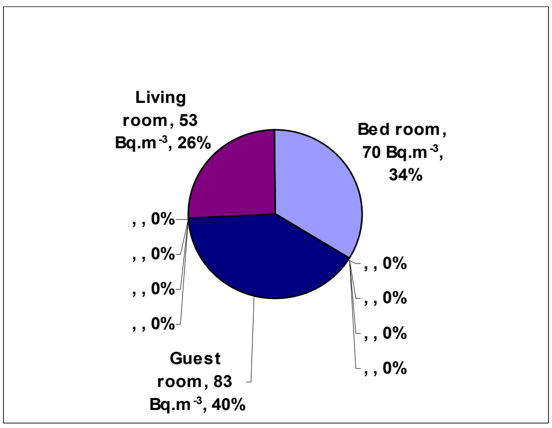



Figure 3. Variation radon level with natural of room of use in ground floor buildings

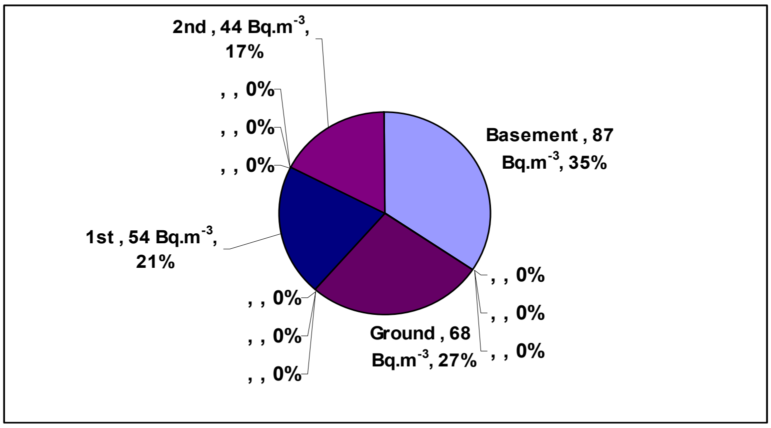



Figure 4. Variation of radon level with differences floors

### *3.2 Differences of Floors*

Here, we discussed the relation between radon concentration and floor elevation (See Table 3 & Figure 4). The average radon concentration in 2nd floors was 44 ± 13 $Bq.m^{-3}$, in 1st floor 54 ± 14 $Bq.m^{-3}$, in ground floor 68 ± 15 $Bq.m^{-3}$ and in basement was 87 ± 16 $Bq.m^{-3}$. The elevated radon concentration in basement and ground floor, as expected, may be due to the closeness of these floors to the soil which considered the main source of radon.

Table 3. relation between radon concentrations ($Bq.m^{-3}$) in different floors

| Floor number | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Basement | 65 | 35 | 211 | 87 ± 16 |
| Ground | 78 | 29 | 200 | 68 ± 15 |
| 1st | 49 | 18 | 79 | 54 ± 14 |
| 2nd | 34 | 11 | 64 | 44 ± 13 |

### *3.3 Buildings Materials*

We selected the ground floor in all studied buildings and compared the radon concentration with the types of building material. Table 4 and Figure 5 shows the average radon concentration in buildings which were built from stones found 90 ± 18 $Bq.m^{-3}$, concrete 78 ± 14 $Bq.m^{-3}$ and blocks 47 ± 12 $Bq.m^{-3}$. The high radon concentration noticed in the stone buildings. This may be due to the low porosity of stones, which did not allow to exchange with outside air. The low average level was in buildings which were built from blocks. This could be due to the high porosity, low thickness of blocks in comparison with the concrete and stones.

Table 4. Variation of radon concentrations ($Bq.m^{-3}$) with the type of building material

| Building material | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Stones | 28 | 30 | 205 | 90 ± 18 |
| Concrete | 26 | 15 | 190 | 78 ± 14 |
| Blocks | 22 | 18 | 179 | 47 ± 12 |

### *3.4 Age of Buildings*

We discuss here, the relation between the radon concentrations in the ground floor at buildings built from blocks but have different ages (See Table 5 & Figure 6). Average radon concentration was found in buildings of ages more than 25 years about 63 ± 15 $Bq.m^{-3}$, in buildings ages 10 - 25 years 51 ± 13 $Bq.m^{-3}$ and in buildings ages less 10 years 39 ± 11 $Bq.m^{-3}$.

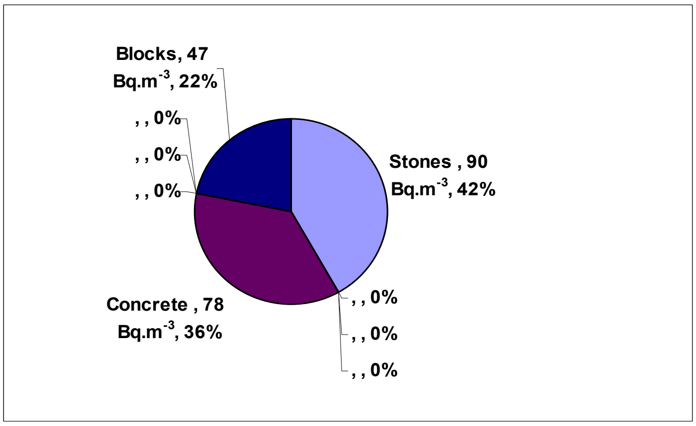



Figure 5. Variation of radon level with different of building materials

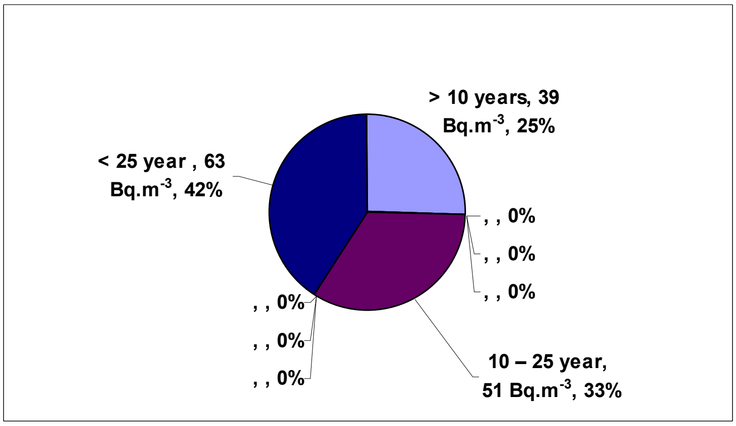



Figure 6. Variation of radon level with different age of building materials

The observed high radon concentration in buildings of ages more than 25 years may be due to the noticeable cracks in the floors and walls and sometimes unfinished walls and floors, which may allow radon gas to seep into the buildings.

Table 5. Variation of radon concentrations ($Bq.m^{-3}$) with buildings ages (years)

| Building age | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Less than 10 | 22 | 21 | 74 | 39 ± 11 |
| 10 - 25 | 8 | 31 | 144 | 51 ± 13 |
| More than 25 | 6 | 47 | 242 | 63 ± 15 |

*3.5 Passive Ventilation Periods*

As we see from Table 6 and Figure 7, these confirmed the essential role played by ventilation periods in reducing the radon levels in buildings.

Table 6. The relation between the ventilation rate (hours) and radon concentration ($Bq.m^{-3}$)

| Ventilation period | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| 0 | 9 | 43 | 217 | 97 ± 15 |
| 1 - 5 | 20 | 51 | 182 | 46 ± 11 |
| 5 - 9 | 21 | 36 | 74 | 37 ± 10 |
| More than 9 hours | 27 | 11 | 28 | 30 ± 10 |

*3.6 Buildings Locations*

Suwaylih town (the study location) divided into six districts. Radon concentrations data in the ground floors was used to compare between different disricts. We found that radon levels inside studied individual building rang from 35 to 211 Bq.m$^{-3}$ with an average 63 ± 13 Bq.m$^{-3}$ (See Table 7 & Figure 8).

## 4. Conclusions

Radon concentrations in buildings in Suwaylih town were carried out using the solid state nuclear track detectors SSNTDs, applying the technique known as time - integrated closed can technique with CR - 39 detectors.

The average radon concentration in buildings in Suwaylih town have been found to be in general low and in acceptable level 62 ± 13 Bq.m$^{-3}$, afew high concentrations were observed in some special places. We conclude that the radon concentration levels in air inside the basement 87 ± 16 Bq.m$^{-3}$ and ground floors 68 ± 15 Bq.m$^{-3}$ of the studied buildings were higher than those of other floors 1$^{st}$ & 2$^{nd}$ floors. According to the age of building, the average radon concentration was higher in older buildings than that in newer ones. The study also showed that the type of use of the room has an effect on the radon concentration. The averages were 83 ± 18, 70 ± 14 and 53 ± 10 Bq.m$^{-3}$ in Guest rooms, Bed room and Living room, respectively.

Table 7. Representation of radon concentration (Bq.m$^{-3}$) and buildings location

| District Name | Frequency | Minimum | Maximum | Mean |
|---|---|---|---|---|
| Al-Kamaliah | 20 | 37 | 112 | 62 ± 11 |
| Al-Rahmaniah | 21 | 40 | 207 | 79 ± 15 |
| Al-Sharqy | 22 | 35 | 186 | 70 ± 13 |
| Al-Fadielah | 19 | 28 | 170 | 64 ± 13 |
| Maysaloon | 18 | 30 | 98 | 58 ± 10 |
| Al-Bashaaer | 16 | 33 | 115 | 51 ± 9 |

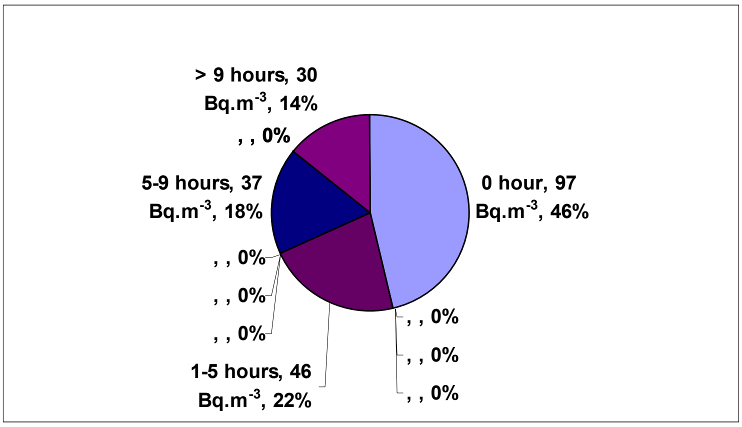



Figure 7. Variation of radon level with passive ventilation periods

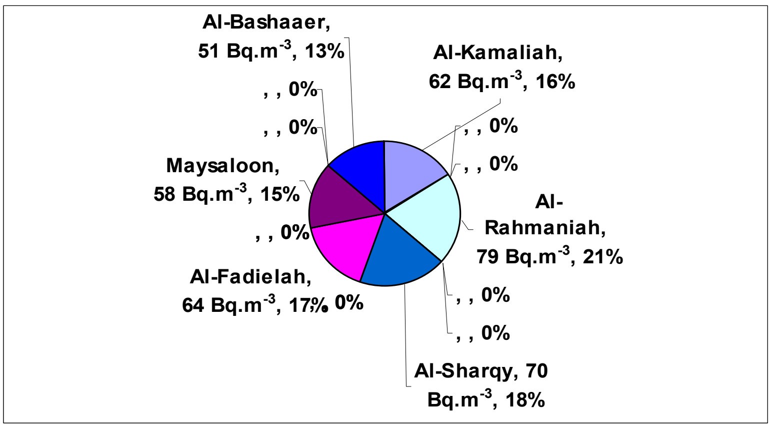



Figure 8. Variation of radon level with buildings locations

It was noticed that the average radon concentration in districts Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon and Al-Bashaaer closely together and found Al-Rahmaniah district had higher average radon concentration 79 ± 15 $Bq.m^{-3}$ and Al-Bashaaer disrict was the lowere one 51 ± 9 $Bq.m^{-3}$. The study showed that the buildings which have the longest ventilation period (more than 9 hours during the day) have the lowest average radon concentration 30 ± 10 $Bq.m^{-3}$, and the buildings with no ventilation period have the highest average radon concentration 97 ± 15 $Bq.m^{-3}$. In addition, the concentration of radon was relatively high 90 ± 18 $Bq.m^{-3}$ in building made of stone while concentration was low 47 ± 12 $Bq.m^{-3}$ in building made of blocks.

## 5. Suggestions

The permissible level of radon exposure recommended by the local or national authority called the action level. When the indoor radon concentration level exceeds the action level, various procedures must be taken to mitigate the indoor radon concentration to alevel less than or equall to the action level. These procedures are called remedial action (Furlan & Tommoasino, 1993). Because the exposure cicumstances the same, the action level is different from one country to another. Each country has especial action level for example the action level in UK, Sweden, China and Australia is 200 $Bq.m^{-3}$ (Hudak, 1996; Vanmarcke, Govaerts, & Oberstedt, 1996).

There are no standard techniques for all situations of exposure. However, the following general procedures may be used to reduce the radon concentration in the study (Suwaylih town):

1) improving the ventilation of the building and increasing under floor ventilation.

2) Sealing floors, walls and cracks.

3) minimize basements area and it must save for storage but not for living.

4) building materials must be selected from areas not rich in uranium and radium.

5) living areas should be chosen properly far from phosphate and granite deposits.

## References

Abumurad, K., & Al-Tamimi., M. (2005). Natural radioactivity due to radon in Soum region. *Jordan. Radiat. Meas., 39*, 77-80. http://dx.doi.org/10.1016/j.radmeas.2004.02.017

Al-Zubaidy, N. (2012). Increse in the Probability of Lung Cancer Disease in Some Homes of Al-Mafraq City, Jordn Caused by Radon. *Hikari Ltd. Adv. Theor. Appl. Mech., 5*(5), 199-207.

Al-Zubaidy, N., & Mohammad, A. (2011). Measurements of Radon Gas Concentrations in Hubras and Harta Villages and Its Effect on Public Health by Application of Nuclear Track Detectors (NTD's). *European Journal of Scientific Research, 66*(3), 404-407.

Al-Zubaidy, N., & Mohammad, A. (2012). Health Effects on Public of Malka Region due to Radon Gas, Using (CR-39) Detector. *Hikari Ltd. Adv. Theor. Appl. Mech., 5*(2), 61- 67.

Anastasion, T., & Christofides, S. (2003). *Indoor radon-222 concentration measurements in Cyprus using high sensitivity portable detectors.*

Bajwa, B. S., & Virk, H. S. (1997). Environmental radon monitoring in dwellings near the radioactive sites. *Amristar-143005, india.radiation measurement, 26*(1), 457-460.

Dixon, D. W. (2002). Radon exposure from cooking with natural gas. *Environmental Radon Newsletter, 32*, 2.

Durrani, S. A., & Badr, A. (1995). Geostatistically controlled field study of radon levels and the analysis of their spatial variation. *Radiation Measurement, 25*(1-4), 656-572. http://dx.doi.org/10.1016/1350-4487(95)00185-H

Durrani, S. A., & Bull, R. K., (1987). *Solid State Nuclear Track Detection, Principles, Methods and Applications. Oxford* (1st ed.). Pergamon press.

Furlan, G., & Tommoasino, I. (1993). Radon monitoring in radioprotection Environmental and or Earth sciences. World scientific puplishing Co. Pte. Ltd.

Gesell, T. F., Johanson Jr, R. H., & Bernhardt, D. E. (1977). Assessment of potential radiological population health effects from radon in liquefied petroleum gas. US. Environmental protection Agency Report EPA - 520/1-75 - 002.

Hudak, P. K. (1996). Distribution of indoor radon and concentrations and uranium – bearing rocks in texas. *Environmental geology, 28*(1), 29-33. http://dx.doi.org/10.1007/s002540050075

Ismail, A. M., Abumurad, K. M., Kullab, M. K., & Al-Bataina, B. A. (1996). Measurements of Rn-222

Concentration in Building Materials Used in Jordan. *Mu'tah Journal for Research and Studies, 11*(3), 201-216.

Jonsson, G. (1995). Radon gas-where from and what to do. *Radiation Measurment, 25*(1-4), 537-546.

Mohammad, A., & Abumurad, K. (2008). Evaluation of radon gas concentration in the air of soil and dwellings of Hawar and Foara villages, using (CR-39) detectors. *Radiat. Meas., 43*, 452-455. http://dx.doi.org/10.1016/j.radmeas.2008.04.074

Paredes, C., Kessler, W. V., Landalt, R. R., Zimemer, P. L., & Paustenbach. (1987). Radionuclide content of Rn-222 emanations from building materials made from phosphate industry waste products. *Health phys, 53*, 33. http://dx.doi.org/10.1097/00004032-198707000-00002

Vanmarcke, H., Govaerts, P., & Oberstedt, S. (1996). Manageability, the clue to the ICRP radon approach. *Environmental International, 22*, 1105-1109. http://dx.doi.org/10.1016/S0160-4120(96)00226-7

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# The Design and Simulation of Single-bit-data Blind Oversampling Data-recovery Circuit for USB2.0 Interface

Ma Xiaoyan[1], Zou Hao[2], Li Yujuan[1] & Xu Tingting[1]

[1] College of Information Engineering, Tai Shan Medical University, Tai'an, Shandong, China

[2] Tai'an power supply company, Tai'an, Shandong, China

Correspondence: Ma Xiaoyan, College of Information Engineering, Tai Shan Medical University, Tai'an 271016, Shandong, China. Tel: 86-135-8383-4589. E-mail: maxiaoyan81@126.com

Received: November 26, 2012 Accepted: December 14, 2012 Online Published: December 25, 2012

doi:10.5539/mas.v7n1p61 URL: http://dx.doi.org/10.5539/mas.v7n1p61

**Abstract**

In order to propose a new single-bit-data blind oversampling data-recovery circuit for the USB2.0 interface, the circuit is designed and simulated correctly by using dynamic sampling window to sample the signal. Based on the dynamic sampling window, the circuit selects the right data from the 5X sampled data and decides the proper next sampling window on the basis of both the edge of sampled data and the position of current sampling window. The proposed circuit by using dynamic sampling window simplifies the sampling algorithm and reduces the scale of circuit compared to conventional circuits. Moreover, this proposed circuit is available on account of the simulation result at the frequency of 480MHz and test vectors of 1000,000 bit based on 0.18 um CMOS technology library.

**Keywords:** blind oversampling, data-recovery, dynamic sampling window

## 1. Introduction

In modern serial data transmission systems, clock synchronization signals are generally not used for transmission, which are replaced by asynchronous mode between transmitter and receiver, in order to reduce the number of the signal lines. In asynchronous mode, the clock signal is unable to achieve strict synchronization, with a possible solution of using blind oversampling data recovery circuit.

There have been several studies on the design of blind oversampling data recovery circuit. The traditional blind oversampling data recovery circuit was firstly introduced in earlier studies (Yang, Farjad-Rad, & Horowitz, 1998; Kyeongho et al., 1995; Kim & Jeong, 2003). Then Part et al. proposed a relatively new circuit design using data selection of the 5X oversampled data sampled from a single data bit, which could reduce more than half numbers of the transistors (Park et al., 2008). This circuit included an X5 bit Sampler, a coarse data recovery block, an Add/Drop FIFO, and a sampling arbitration circuit. The general principle of this circuit was that the 5-bit oversampled data were sampled from the serial input single-bit data with 5 times sampling frequency by the 5X bit sampler. Corresponding to the phase of level jumping, 1-bit data was chosen from 5-bit input data and then transferred into the FIFO. This Add/Drop FIFO played a very important role in getting an accurate data. Because in practical data transmission, a data may be omitted or repeatedly sampled by the coarse data recovery circuit owing to the signal jitter or the frequency offset between the transmitter and receiver. In the Add/Drop FIFO block, if data recovery circuit missed a sampling data, a new data would be added in Add/Drop FIFO, which was modulated by the control circuit. While if a data was repeatedly sampled, which would be cut off in Add/Drop FIFO. In this way, the data transmission accurate would be guaranteed.

However, blind oversampling data recovery circuit has been challenged by the high transmission speed USB2.0 interface, which is used in communication between computer and peripheral equipment. Currently, USB 2.0 interface has been proved as a relatively simple and reliable interface for short-range data communication and applied in several special integrated chips. And there would be more and more demand for this kind of digital device integrating USB interface. In order to satisfy this increasing demand with a lower cost, reducing the circuit scale of USB2.0 interface would help to cut down the power consumption. Thus a smaller and simpler circuit would be preferred.

In this paper, we propose a more simple single data bit blind oversampling data recovery circuit, with a simulation results in the frequency of 480MHz. In this circuit, the input serial signal is sampled by a dynamic sampling window, and the jump phase of the current data as well as the next dynamic sampling window are determined by the jump phase of both current sampling data and the data in its front-adjacent sampling window. Generally, USB 2.0 protocol uses NRZI coding, which ensures the length of continuous high level will not be longer than 6 bits in the serial data (Compaq & Intel, 2000). Thus the jump data are able to be used in synchronizing transmitter and receiver, also used to control the frequency shift between the transmitter and receiver. Compared to the traditional blind oversampling data recovery circuit and the circuit reported by Park et al, our circuit design and algorithm are relatively simpler and easier, with a much smaller hardware size.

## 2. Circuit Structure

### *2.1 The Traditional Blind Oversampling Data Recovery Circuit*

Figure 1 shows the diagram of traditional blind oversampling data recovery circuit in the USB receiver. The circuit samples the input data with 3 times oversampling frequency using a 24-phase-multiphase clock. The 24 bits oversampling data are transmitted into FIFO1 and the edge detector simultaneously. Then the received bit data would be converted into a byte data by a bit/byte controlling synchronizer. The data are processed into 8 bytes in FIFO2 and transmitted to the output as the recovery data. Because there are two FIFO in this circuit, more hardware resources are required.

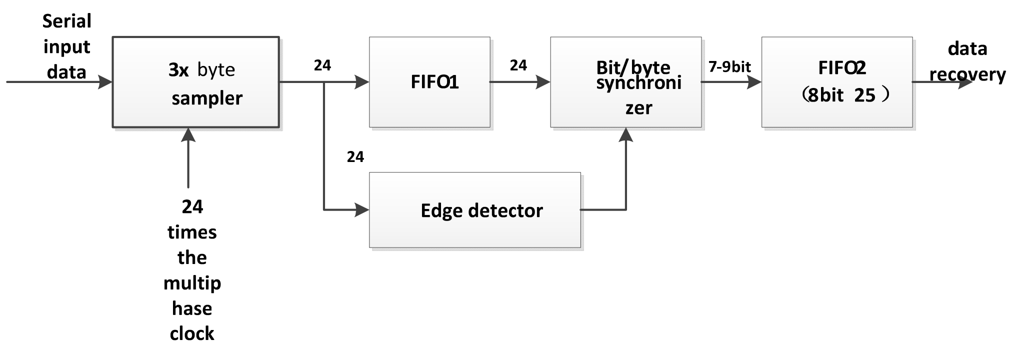



Figure 1. The diagram of traditional blind oversampling data recovery circuit

### *2.2 Blind Oversampling Data Recovery Circuit Reported by Park et al. (2008)*

Figure 2 presents the structure of the blind oversampling data recovery circuit reported by Park et al. The serial input data are first sampled with 5X sampling frequency by a 5X sampler. Then this sampling data are transmitted into FIFO by controlling MUX through a phase selector. Considering to the signal jitter and frequency shift between the transmitter and receiver, the sampling data may be lost or repeatedly sampled. Thus an error detector and an Add/Drop FIFO are adopted to add or cut off a data based on the detected error, which in turn to promise an accurate recovery data obtained.

This circuit is simpler than the traditional one. However, the algorithm of both the phase selection and the error detector are relatively complex. Also the implementation of the Add/Drop FIFO is quite difficult.

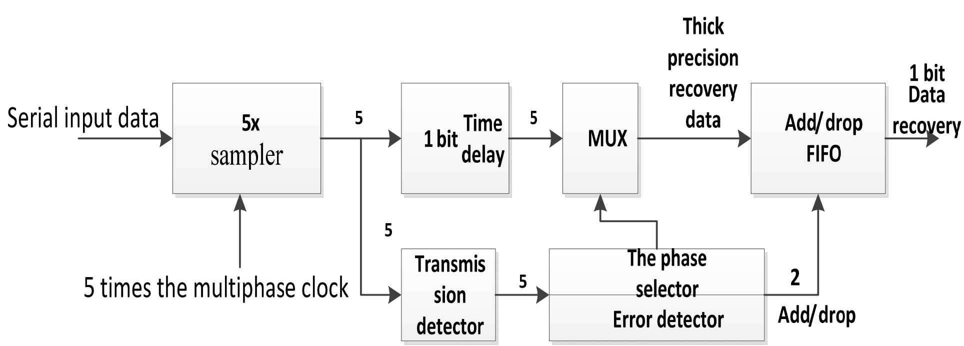



Figure 2. The diagram of blind oversampling data recovery circuit in (Park et al., 2008)

*2.3 The New Blind Oversampling Data Recovery Circuit in Our Study*

The circuit in our study is using a modifying phase sampling algorithm on the basis of the blind oversampling data recovery circuit reported by Park et al. (2008). A dynamic rather than a fixed sampling window is used to sample input signals. This dynamic sampling window is shifted based on the jumping phase of the input data, thus it could be used to reduce or even avoid the errors from data missing or repeatedly sampling owing to the clock synchronization. In this way, the circuit will be simplified by using a general FIFO instead of the Add/Drop one, as well as without the error detector.The structure of this circuit is showed in Figure 3.

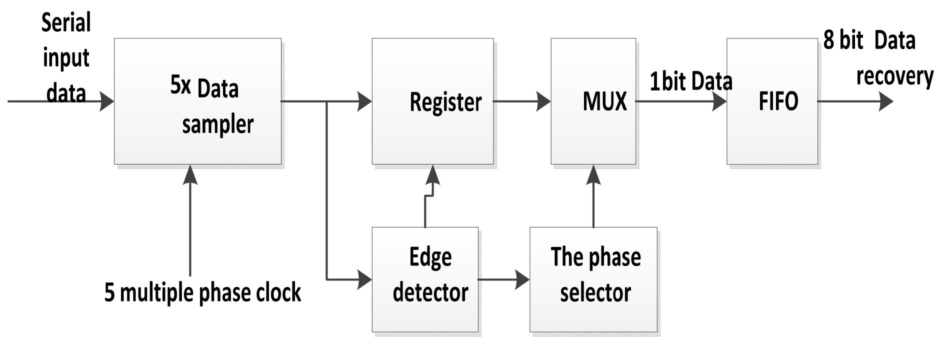



Figure 3. The diagram of a modified blind oversampling data recovery circuit in our study

This circuit includes a 5X data sampler, a shift register, an edge detector, a phase selector, a 7-1 MUX, and a FIFO (convert 1 bit serial data into 8 bit parallel data). Five sampling clocks in 5X data sampler work in the frequency of 480MHz, with the adjacent lock phase difference of $2\pi/5$. It is worthy to point that this circuit works in a 5-clock-input-signal alternately sampling mode, which could reduce the high frequency interference without using 2.4 GHz clock signal. In addition, in the sampler, a buffer constituted by two level inverters is used to cushion the sampling results to solve the problem caused by the edge sampling data and get a correct level of the sampling data.

The principle of the circuit is that 1bit serial input data is firstly sampled 5 times at a same time-interval by the 5x bytes sampler, which is used a 5 times multiphase clock as a reference clock. Then the received sampling data are simultaneously transmitted to the edge detector and the shift register. In the edge detector, the last bit of the previous sampling data and the new sampling 5 bits data are stored to calculate the jumping edge position of this 6-bit data. Then the calculation results are transferred into the phase selector. In the shift register, the sampling data are shift stored according to the sampling sequence. This shift register is at least 7 bits to meet the requirement of the dynamic window. Based on the locations of rising and falling edges, as well as the last sampled data position, the current sampling position can be obtained by the phase selector, which is also used to control MUX to choose the right data as an input to the FIFO. Lastly in FIFO, the 1bit data is converted into 8bit data as the recovered data.

## 3. Sampling Data Selection

In this circuit, five clocks are used to sample the serial input data and different shifts are obtained after sampling, with the same shift between adjacent sampling data. Figure 4 shows the sampling principle of the 5X phase clock. Five sampling data (D[0]~D[4]) are received in a sampling window at the rising edge of the clock.

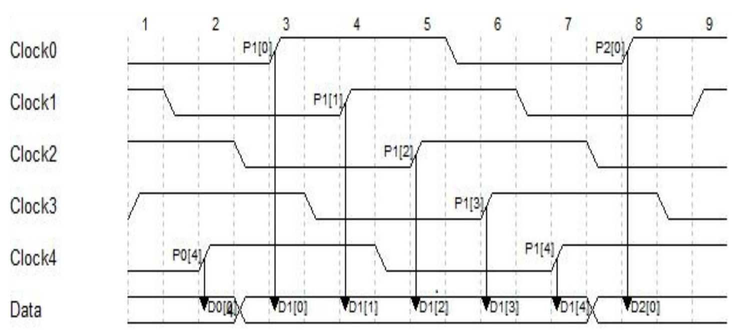



Figure 4. The sequence diagram of the 5X phase clock

The phase selection algorithm in our study is modified from the design reported by Park et al. (2008). In their study, a fixed sampling window was adopted for blind oversampling data recovery circuit. Five clocks, from clock0 to clock 4, sequentially sampled the input data, which would then determine the sampling phase and finally constitute the fixed sampling window P[0]~P[4]. In this design, because the frequency offset between the transmitter and receiver is cumulative, fixed sampling window may contain the adjacent data information, which would make data sampling algorithm more complex and also increase the hardware cost. In our study, the fixed sampling window is replaced by a dynamic one, the effect caused by frequency offset would be partially reduced and most current sampling data would fall into the sampling windows. The position of the current sampling window is determined by the last sampling results. In addition, it is worthy to point that, more data need to be stored in the register using the dynamic sampling window, at least 6 bits, adding 1 bit delay, so 7 bits in total, which can be achieved with a 7-bit shift register.

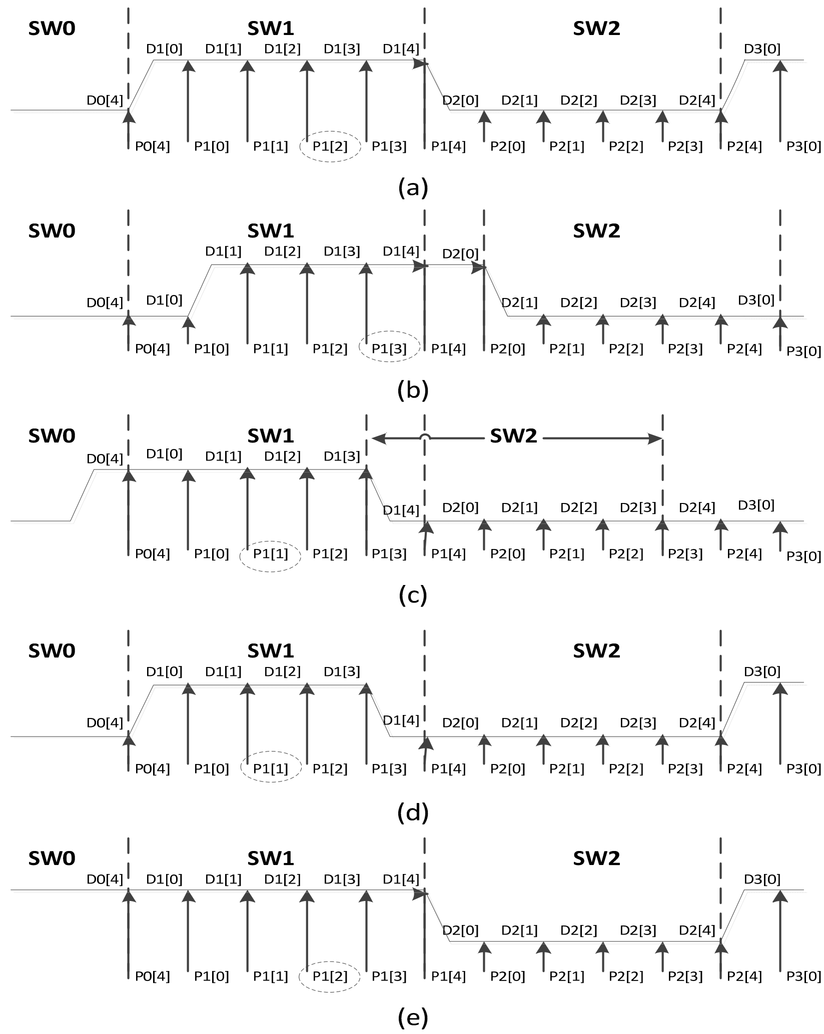



Figure 5. Sequence diagram of the data sampling

Figure 5 presents the sequence diagram of the data sampling selection. Supposing the current sampling window is SW1, if the jumping edge of the bus data falls between P0[4] and P1[0], the sampling result will be D1[2], which is used to determine the next sampling window, that is P1[4]~P2[4], shown in Figure 5(a). If the jumping edge of the bus data falls between P1[0] and P1[1], the sampling result will be D1[3] and the next sampling window will be P2[0]~P2[4], shown in Figure 5(b). If the jumping edge of the bus data falls between P1[3] and P1[4], the sampling result and the next sampling window will be D1[1] and P1[3]~P2[3], respectively, shown in Figure 5(c). If there are two jumps in the sampling window in P0[4]~P1[0] and P1[3]~P1[4] , respectively, then the sampling result will be D1[1], determining the next sampling window P1[3]~P2[3], shown in Figure 5(d). If no jumping data in the sampling window, the sampling result will be D1[2], and the next sampling window is

P1[4]~P2[4], shown in Figure 5(e). However, if the sampling result is not in the list above, there may be a greater data jitter or a larger frequency shift between the transmitter and receiver, which is impossible to recover an accurate data. These different cases results are also summarized in Table 1.

Table 1. The sampling results in current sampling window P0[4] ~P1[4]

| | Case1 | Case2 | Case3 | Case4 | Case5 |
|---|---|---|---|---|---|
| Bus data jump | P0[4]~P1[0] | P1[0]~P1[1] | P1[3]~P1[4] | P0[4]~P1[0], P1[3]~P1[4] | Don't jump |
| Sampling results | D1[2] | D1[3] | D1[1] | D1[2] | D1[2] |
| The next sampling window | P1[4]~P2[4] | P2[0]~P3[0] | P1[3]~P2[3] | P1[3]~P2[3] | P1[4]~P2[4] |

## 4. Simulation and Analysis

In this paper, HSPICE is adopted to implement the circuit simulation, with a 0.18um technology library. The FIFO block is removed in order to get a higher simulation speed.

### *4.1 The Generation of Test Vector*

Firstly, a simulation is conducted for signal jitter as well as the frequency offset between transmitter and receiver. The sampling frequency is fixed at 480MHz and the frequency of the serial input data is 480*(1±1/1000) MHz. A pseudo random data are generated using MATLAB to modulate the random jitter of the serial input signal. Based on this method, a serial input data with the length of 1,000,000,000,000-bit are generated as the test vector, which are used in simulation for the blind oversampled data recovery circuit.

### *4.2 Simulation Results*

Using frequency at 480MHz, the simulation results show that this circuit can be used to accurately recover the serial input data, even the signal with a frequency offset and a signal jitter. Some simulation results are presented in Figure 6. As can be seen, the input signals are recovery accurately, which are comparable with the out data. The simulation results also suggest that this circuit design can be applied in the receiver accordance with USB 2.0 protocol.

Figure 6. Some simulation results

## 5. Conclusion

In this paper, we proposed a new blind oversampled data recovery circuit, including a 5X sampler, an edge detector, a phase selector, a MUX block, and a FIFO block. Through modifying the traditional phase selection algorithm, we used a dynamic sampling window instead of the previous fixed sampling window to sample the input data, which can simplify the process of data recovery and also reduce the errors from data missing or data repeatedly sampling in the traditional recovery processing owing to the signal jitter and the frequency offset between transmitter and receiver in asynchronous communication.

We also conducted the circuit simulation with frequency of 480 MHz, with accurate data recovery results. So it suggests that this circuit can be used in USB 2.0 system with a less cost and a more simple design, which is more suitable for integration in SOC chips.

**References**

Compaq, I., & Intel, L. (2000). Universal serial bus specification revision 2.0 in USB Implementers\ Forum.

Kim, J., & Jeong, D. K. (2003). Multi-gigabit-rate clock and data recovery based on blind oversampling. *Communications Magazine, IEEE, 41*, 68-74. http://dx.doi.org/10.1109/MCOM.2003.1252801

Kyeongho, L., Sungjoon, K., Gijung, A., & Jeong, D. K. (1995). A CMOS serial link for fully duplexed data communication. *IEICE Transactions on Electronics, 78*, 601-612.

Park, S. H., Choi, K. H., Shin, J. B., Sim, J. Y., & Park, H. J. (2008). A single-data-bit blind oversampling data-recovery circuit with an add-drop FIFO for USB2. 0 high-speed interface. *IEEE Transactions on Circuits and Systems II: Express Briefs, 55*, 156-160. http://dx.doi.org/10.1109/TCSII.2007.911791

Yang, C. K. K., Farjad-Rad, R., & Horowitz, M. A. (1998). A 0.5-µm CMOS 4.0-Gbit/s serial link transceiver with data recovery using oversampling. *IEEE Journal of Solid-State Circuits, 33*, 713-722. http://dx.doi.org/10.1109/4.668986

Modern Applied Science; Vol. 7, No. 1; 2013
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

# Relationship between Factors of Construction Resources Affecting Project Cost

Ismail Abdul Rahman[1], Aftab Hameed Memon[1] & Ahmad Tarmizi Abd. Karim[1]

[1] Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, Malaysia

Correspondence: Aftab Hameed Memon, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, Malaysia. Tel: 60-14-272-5620. E-mail: aftabm78@hotmail.com, aftabm78@gmail.com

Received: October 25, 2012 Accepted: December18, 2012 Online Published: December 25, 2012

doi:10.5539/mas.v7n1p67 URL: http://dx.doi.org/10.5539/mas.v7n1p67

**Abstract**

The success of any construction project highly depends on how proper and effective the management of construction resources flow. Studies show that various resources factors affected cost management and have resulted to significant amount of cost overrun worldwide. However, a few investigations had been carried out in Malaysia regarding the effect of resources in construction industry. Hence, this study focuses on identifying significant resource factors causing construction cost overrun and also assessing the relationship between these factors. Data collection was carried out through a structured questionnaire survey consisting of 20 factors identified through a comprehensive literature review. Data was analyzed using statistical software package SPSS. The Cronbach's alpha of the data was 0.910 which means that the collected data was highly reliable. The factors were ranked through mean rank approach and it was found that 3 most significant factors are "fluctuation of prices of materials", "cash flow and financial difficulties faced by contractors" and "shortages of materials". While the least significant factors in causing cost overrun are "insufficient numbers of equipment", "relationship between management and labour", and "labour absenteeism". The result of Spearman test indicates that "cash flow and financial difficulties faced by contractors" with "financial difficulties of owner" correlate strongly at a significant level of 0.752. This identification of factors and relationships will help construction community in controlling resopurce factors for achieving project completion within the budget.

**Keywords:** construction management, construction resource factors, cost overrun, Johor

## 1. Introduction

Money is always of special importance to those involved in construction project. Hence, completion of any project within the estimated cost of project is the basic criteria for success of any project. The success of any project is highly depends on adequate availability and efficient management of various resources. Hence, prior and adequate arrangement for provision of resource involved in construction such as type and quantity of material, manpower, machines and finance are required at each stage of construction. There are various factors that cause failing resources management. More common, the importance of resource management is not considered properly in the conceptual and planning phases of a construction project which resulted in construction cost overrun. Therefore, this leads to the project having inadequate budget to perform its vital function. The necessity of proper budgeting for a project, an explanation of resource management, and the economic benefits that would accrue to the project are addressed. In order to control cost, equipment and labour should be utilized in the most efficient way possible.

Managing resources in the framework of civil engineering construction sector is usually an extremely complex task. Factors contribute to this complexity include the variety and great number of existing resources of both human and material, the diversity of tasks that each working unit is able to execute, the performance of each working unit, the involved costs, and the spatial distribution of all resources over the different places, leading to the need for displacement from one site to another. All these important factors imply a high number of variables, resulting in a somewhat difficult optimization process. The basic objective of resource management is to supply and support the project so that established time objectives can be met and costs can be kept within the project budget (Just & Murphy, 1994).

In Malaysia, many projects are facing cost overrun (Ali & Kamaruzzaman, 2010; Endut, Akintoye, & Kelly, 2009; Sambasivan & Soon, 2007). One of the main causes of cost overrun is ineffective resource managements.

There are various resource related factors which lead to failure of resource management resulting in construction cost overrun. Hence, this study is aimed at investigating construction resources-related factors that cause construction cost overrun in Malaysian construction industry. However, the scope of this paper is limited to investigations in Johor state only.

## 2. Related Works

Completion of any project within the estimated cost is the basic criteria for the success of any construction project. Primary target of practitioners involved in construction projects is to complete the project within budgeted cost regardless of size and complexity of project. However, completion of any project highly depends on the construction resources. Project resources provide the means for accomplishing the work objectives (Padilla & Carr, 1991). Construction resources management is the most important factor contributing to cost success (Meeampol & Ogunlana, 2006).

Construction resources management has a high and significant relationship with cost performance for successful projects (Meeampol & Ogunlana, 2006). As cited by (Zujo, Car-Pusic, & Brkan-Vejzovic, 2010) in a multiannual research conducted in Croatia from 1996 till 1998 as part of the scientific project Construction Project Risk and Resource Management, the occurrence of price overrun was observed in no less than 81% of the projects. Previous studies reveal that there are various construction resource related factors which significantly influence construction cost. Enshassi, Al-Najjar, and Kumaraswamy (2009) found that increment of construction materials prices due to continuous border closures, delay in construction and supply of raw materials and equipment by contractors, fluctuations in the cost of building materials, and resources constraint of funds and the associated auxiliaries not ready, were among the top ten factors affecting construction cost. Financial difficulties of owner and contractor were ranked as the first problems affecting construction cost in Vietnam (Le-Hoai, Lee, & Lee, 2008). If the contractor can minimize problems such as inefficient use and lack of construction equipment and shortage of quality material, the construction budget can be reduced (Meeampol & Ogunlana, 2006).

In extension from the above review works in uncovering resource related factors causing cost overrun, the comprehensive literatures review work has identified a total of 20 factors which are been classified into four categories, i.e. material, manpower, machinery and money as shown in Table 1.

Table 1. Factors causing construction cost overrun

| Category | Resources-related factor | Source |
|---|---|---|
| **Material** | Fluctuation of prices of materials | (Ameh, Soyingbe, & Odusami, 2010; Enshassi et al., 2009; Koushki, Al-Rashid, & Kartam, 2005) |
| | Shortages of materials | (Le-Hoai et al., 2008; Long, Ogunlana, Quang, & Lam, 2004; Omoregie & Radford, 2006) |
| | Changes in material specification and type | (Moura, Teixeira, &Pires, 2007) |
| | Delay in delivery of materials | (Creedy, 2005; Latif, Abidin, & Trigunarsyah, 2008; Moura et al., 2007) |
| **Manpower** | High cost of labour | (Ameh et al., 2010; Azhar, Farooqui, & Ahmed, 2008; Koushki et al., 2005) |
| | Shortage of technical personnel (skilled labour) | (Creedy, 2005) |
| | Severe overtime | (Long et al., 2004) |
| | Labour productivity | (Moura et al., 2007) |
| | Labour absenteeism | (Moura et al., 2007) |
| | Shortage of site workers | (Ameh et al., 2010; Azhar et al., 2008; Le-Hoai et al., 2008) |
| **Money** | Financial difficulties of owner | (Koushki et al., 2005; Le-Hoai et al., 2008; Long et al., 2004; Moura et al., 2007; Oladapo, 2007) |
| | Delay payment to supplier /subcontractor | (Moura et al., 2007) |
| | Delay in progress payment by | (Creedy, 2005) |

| | | |
|---|---|---|
| | owner | |
| | Cash flow and financial difficulties faced by contractors | (Creedy, 2005; Le-Hoai et al., 2008; Long et al., 2004) |
| | Mode of financing, bonds and payments | (Ameh et al., 2010; Azhar et al., 2008; Omoregie & Radford, 2006) |
| | Poor financial control on site | (Ameh et al., 2010; Azhar et al., 2008) |
| **Machinery** | Equipment availability and failure | (Creedy, 2005; Moura et al., 2007) |
| | Late delivery of equipments | (Creedy, 2005; Latif et al., 2008; Moura et al., 2007) |
| | Insufficient number of equipments | (Moura et al., 2007) |
| | High cost of machinery and its maintenance | (Ameh et al., 2010; Azhar et al., 2008) |

Table 1 shows 20 resource related factors which are been classified into four common types of resource groups. These resources are commonly encounted in any construction project. The resources are further discussed as in the following sections.

*2.1 Material Resource*

Materials are the essence in the construction industry which represents a substantial proportion of the total value of the project. Material related issue contributes to cost overrun run (Koushki et al., 2005). Hence, efficient material management is an important criterion for success of any project. A material management system includes the fundamental functions required in any construction project such as identifying, acquiring, storing, distributing and disposing of materials. Regular and adequate supply of the materials is very very critical tasl as late or irregular delivery or wrong types of material delivered during construction affect the utilization of other resources like manpower and machinery. This leads to poor productivity, time delay and cost overrun.

*2.2 Manpower Resource*

Manpower or human resource labour are very significant resources which play important role in success of any project. Good results certainly cannot be achieved without the adequate availability of skilled and unskilled manpower, most suitable allocation and management of human or manpower resource. Expected construction progress can be achieved only through the attainment of effective man-hour effort and the meeting of scheduled mile stone dates. Effective manpower management can reduce labour costs and thereby increase profits for company. In developing countries, poor labour productivity is a severe problem (Kaming, Olomolaiye, Holt, & Harris, 1997). Hence, effective manpower management and improvement in labour productivity is critical need for reducing labour costs and thereby increase profits for company.

*2.3 Money or Finance*

Money or finance is the first and foremost resource required for any construction work. The design and specifications of a project depend upon it, and without sufficient fund, any project cannot be completed. Hence, availability of sufficient funds and effective financial management are very important aspects in any project. Financial management is the use of financial or accounting information at all levels to assist in planning, making decisions and controlling the activities of an enterprise (Lock, 1993). Without proper management of the money or finance, the management of other resource becomes useless.

*2.4 Machines or Equipment Resources*

Equipment Resources has an advantage over manpower resource as it can work under adverse circumstances continuously, requires less manpower and other facilities. The selection and utilization of equipment in a project must be an integral part of the total plan. The type and number of the equipments required in any project depends on the nature of the project. It affects significantly on construction cost.

## 3. Methods

Data was collected through a structured questionnaire survey carried out among the personnel involved in construction industry. The survey was conducted in Johor state of Malaysia. A total of 100 questionnaire sets were distributed and 53 completed responses were received and analyzed statistically for assessing the significance level of resource factors and also correlation between these factors. The tests adopted for this analysis are described in the following sections:

*3.1 Reliability Test*

A reliability test was performed on the collected data to determine its degree of consistency. The Cronbach α coefficient is computed for data consistency. The accepted reliability is when Cronbach α is greater than 0.3. If α is greater than 0.7, the collected data is considered as highly reliable (Wong & Cheung, 2005; Yang & Ou, 2008).

*3.2 Ranking*

A five point Likert-scale of 1 to 5 was adopted to assess the likelihood of each of the identified factor in causing construction cost overrun, where scales of 1 = extremely significant, 2 = most significant, 3 = moderately significant, 4 = significant, and 5 = not significant. The studied factors were ranked based on the mean rank score. Lower mean rank score represents the higher the ranking is. The equation used to compute for the mean rank is

$$M_R = \frac{n\overline{R}}{R_{\max}} \tag{1}$$

Where, $M_R$ is mean rank, $\overline{R}$ is individual mean rank of cause, $R_{max}$ is the maximum individual mean rank of cause, and n is the number of causes. The determination of the significance of the causes is based on the mean rank score.

*3.3 Correlation Analyses*

The strength of associations of pairs of variables understudy was determined by correlation relationships. The 3 commonly used methods for ascertaining the strength of association between 2 variables is the Pearson correlation method, the Spearman rank correlation method and the Chi square test of independence method.

As data collected in this study is non-parametric and ordinal variables, the powerful method of examining the relationship between pairs of variables is by using Spearman's rank order correlation (Bryman & Cramer, 2002). Spearman's formula is given as

$$\rho = 1 - \frac{6\sum d^2}{n\left(n^2 - 1\right)} \tag{2}$$

where,

ρ Spearman coefficient

d the difference between ranks

n number of subjects or pairs of ranks

The correlation coefficient ρ ranges from -1.0 to +1.0. The closer ρ is to +1 or -1, the more closely the two variables are related. The value of ρ close to 1 implies there is strong positive linear relationship between the two variables while the value of ρ close to -1 shows a strong negative linear relationship between the two variables (Daud, Ahmad, & Yusof, 2009). Ideally, the correlation coefficient value of ± 1 is said to be a perfect correlation. If the correlation coefficient value lies between ± 0.5 and ± 1, it is said to have a high degree of correlation. For correlation coefficient value between ± 0.3 and ± 0.5, the degree of correlation is moderate. Low degree of correlation occurs when the correlation coefficient lies between ± 0.1 and ± 0.3. Meanwhile, zero coefficient value represents no correlation at all (Cohen, 1988).

## 4. Results and Discussion

The respondents involved in the survey have had several years of experience in handling various types of projects. The demographic of the respondents participated in survey are summarized in Table 2. The table indicates that majority of the respondents, i.e. 43 out of 53 (81.1%) respondents are experienced in handling large construction projects, i.e. project with contract exceeding RM 5 million (Abdullah, Aziz, & Rahman, 2009). 52.8% of the respondents have experience of handling building projects, 26.4% respondents are experienced in handling infrastructure project, and 20.8% respondents are involved in both building and infrastructure projects.

Table 2. Demographic of respondents

| | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| **Type of Organization** | | | |
| Client | 8 | 15.1 | 15.1 |
| Consultant | 11 | 20.8 | 35.9 |
| Contractor | 34 | 64.1 | 100 |
| **Type of Project** | | | |
| Building | 28 | 26.4 | 26.4 |
| Infrastructure | 11 | 52.8 | 79.2 |
| Build-Infra | 14 | 20.8 | 100 |
| **Size of Project (RM)** | | | |
| < 5 Million | 10 | 18.9 | 18.9 |
| 5 – 10 Million | 10 | 18.9 | 37.8 |
| 10 – 50 Million | 22 | 41.5 | 79.3 |
| > 50 Million | 11 | 20.7 | 100 |

*4.1 Reliability Test*

Data from each category of questionnaire were analyzed for its Cronbach α value. This was to ensure that the data collected are valid and reliable for further analysis. Cronbach α value for overall data was 0.910 and Table 3 shows values of Cronbach α for each category of the factors are in the range of 0.736 to 0.883. This range is considered high compared to cut-off value of 0.7. Thus, the reliability of the questionnaire is assured. Certainly, this indicates that the questionnaire data are valid and reliable.

Table 3. Reliability test results

| Category of data | Cronbachα |
|---|---|
| Material | 0.736 |
| Manpower | 0.745 |
| Money | 0.883 |
| Machinery | 0.760 |

*4.2 Extent of Cost Overrun*

Respondents were asked about the extent of cost overrun as compared to the contracted cost of the various projects they have handled. The results are presented in Figure 1. Figure 1 indicates that majority of the respondents stated that cost overrun in construction projects is a common issue. Only 15.09% of the respondents testified that their projects had been executed within the estimated cost. A significant number of respondents (37.74%) mentioned that they had experienced cost overrun ranges from 1% to 5% of contracted cost. This followed by 28.30% of the respondents stated of 5-10% of cost overrun. However, 11.32% respondents mentioned that cost overrun was above 15% of contracted cost and only 7.55% responses show that cost overrun ranging from 10% to 15%.

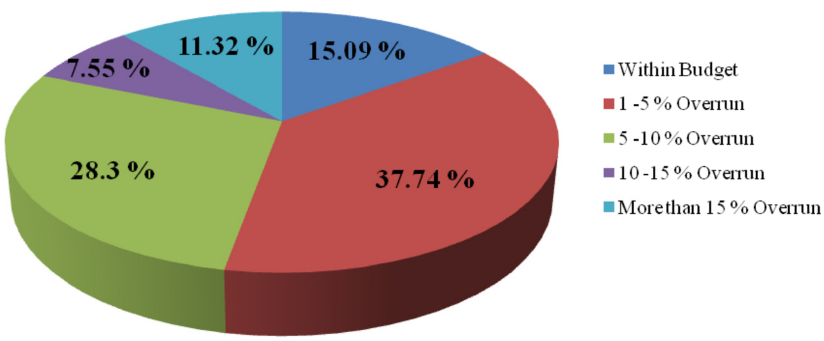



Figure 1. Extent of cost overrun

*4.3 Ranking of Resource Related Factors*

In ranking analysis, the SPSS 17 software was used to compute the mean rank of the resource related factors causing construction cost overrun. The results of the analysis are given in Table 4.

Table 4. Rank analysis results

| Factor | Mean rank | Rank | Category |
|---|---|---|---|
| Fluctuation of prices of materials | 10.74 | 1 | Material |
| Cash flow and financial difficulties faced by contractors | 10.73 | 2 | Money |
| Shortages of materials | 10.18 | 3 | Material |
| Shortage of site workers | 10.08 | 4 | Manpower |
| Financial difficulties of owner | 9.37 | 5 | Money |
| Mode of financing, bonds and payments | 9.31 | 6 | Money |
| Changes in Material Specification and type | 8.46 | 7 | Material |
| Delay in progress payment by owner | 8.46 | 7 | Material |
| Poor financial control on site | 8.46 | 8 | Money |
| labour productivity | 8.33 | 9 | Manpower |
| Late delivery of materials | 8.24 | 10 | Material |
| Delay payment to supplier/subcontractor | 8.24 | 10 | Money |
| Late delivery of equipments | 8.20 | 11 | Machinery |
| High cost of labour | 7.89 | 12 | Manpower |
| High cost of machinery and its maintenance | 7.88 | 13 | Machinery |
| Equipment availability and failure | 7.51 | 14 | Machinery |
| Labour Absenteeism | 7.08 | 15 | Manpower |
| Shortage of technical personnel (skilled labour) | 6.71 | 16 | Manpower |
| Severe overtime | 6.70 | 17 | Manpower |
| Insufficient Numbers of equipment | 5.05 | 18 | Machinery |

Table 4 shows that fluctuation of prices of materials is an extremely significant factor affecting construction cost. Fluctuation of material cost can be caused by various factors. Monopoly of suppliers could be one of main reasons of fluctuation of prices. Unavailability of construction materials locally can also affects the cost of material. However, Enshassi et al. (2009) ranked fluctuation of material prices as the fourth most important factors affecting construction cost in Gaza.

Second most significant factor is cash flow and financial difficulties faced by contractors. This factor has been found to be the most significant in large MARA construction projects (Memon, Rahman, Abdullah, &Azis, 2010). Financial difficulties faced by contractor were ranked as the fourth major factor causing cost overrun in Vietnam construction industry (Le-Hoai et al., 2008). In a study of Ghana, this factor was rated as 5th major factor causing cost overrun (Frimpong, Oluwoye, & Crawford, 2003).

The third most significant factor as indicated in Table 4 is the shortages of materials. However, previous studies have shown that this factor is moderately important factor affecting construction cost. In the study of cost escalation in Nigeria (Omoregie & Radford, 2006) found that shortage of material was ranked as sixth significant factor. While, in Vietnamese construction projects, practitioners have ranked this factor as the 9th most significant (Le-Hoai et al., 2008). In Ghana, this factor was the 15th significant cause affecting construction cost (Frimpong et al., 2003).

*4.4 Relationship between Factors*

Relation between pairs of variables was examined by using Spearman's rank order correlation. The correlation analysis of the factors is shown in Table 5.

Table 5. Correlation between construction resources related factors causing cost overrun

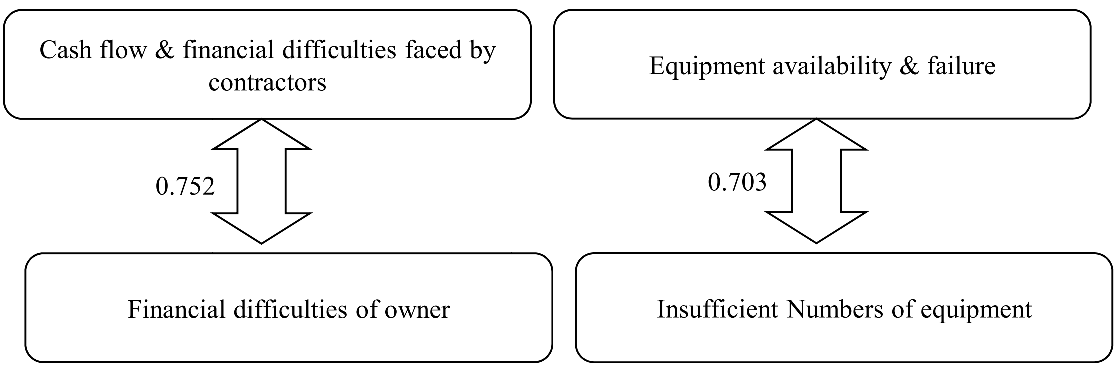
| Factor | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.000 | .437** | .362** | .117 | .268** | .185* | .004 | .377** | .242** | .349** | .289** | .100 | .070 | .247** | .386** | .346** | .210* | .117 | .029 | .205* |
| 2 | .437** | 1.000 | .533** | .543** | .271** | .369** | .305** | .390** | .370** | .525** | .359** | .338** | .292** | .324** | .440** | .422** | .450** | .543** | .378** | .386** |
| 3 | .362** | .533** | 1.000 | .418** | .353** | .360** | .446** | .512** | .575** | .426** | .365** | .359** | .328** | .235** | .333** | .434** | .537** | .418** | .513** | .423** |
| 4 | .117 | .543** | .418** | 1.000 | .291** | .208* | .387** | .263** | .400** | .378** | .344** | .436** | .365** | .298** | .275** | .324** | .535** | 1.000** | .467** | .422** |
| 5 | .268** | .271** | .353** | .291** | 1.000 | .254** | .294** | .285** | .371** | .166 | .336** | .254** | .380** | .240** | .277** | .288** | .361** | .291** | .418** | .612** |
| 6 | .185* | .369** | .360** | .208* | .254** | 1.000 | .499** | .616** | .416** | .515** | .506** | .358** | .302** | .335** | .303** | .291** | .272** | .208* | .317** | .187* |
| 7 | .004 | .305** | .446** | .387** | .294** | .499** | 1.000 | .463** | .547** | .498** | .496** | .457** | .428** | .353** | .408** | .370** | .401** | .387** | .489** | .486** |
| 8 | .377** | .390** | .512** | .263** | .285** | .616** | .463** | 1.000 | .397** | .605** | .572** | .431** | .264** | .494** | .403** | .491** | .340** | .263** | .262** | .274** |
| 9 | .242** | .370** | .575** | .400** | .371** | .416** | .547** | .397** | 1.000 | .488** | .343** | .379** | .415** | .193* | .180* | .331** | .500** | .400** | .461** | .406** |
| 10 | .349** | .525** | .426** | .378** | .166 | .515** | .498** | .605** | .488** | 1.000 | .512** | .524** | .508** | .455** | .474** | .498** | .463** | .378** | .420** | .303** |
| 11 | .289** | .359** | .365** | .344** | .336** | .506** | .496** | .572** | .343** | .512** | 1.000 | .599** | .559** | .754** | .581** | .590** | .434** | .344** | .423** | .478** |
| 12 | .100 | .338** | .359** | .436** | .254** | .358** | .457** | .431** | .379** | .524** | .599** | 1.000 | .724** | .507** | .532** | .619** | .426** | .436** | .433** | .373** |
| 13 | .070 | .292** | .328** | .365** | .380** | .302** | .428** | .264** | .415** | .508** | .559** | .724** | 1.000 | .469** | .413** | .535** | .524** | .365** | .481** | .459** |
| 14 | .247** | .324** | .235** | .298** | .240** | .335** | .353** | .494** | .193* | .455** | .754** | .507** | .469** | 1.000 | .613** | .519** | .272** | .298** | .256** | .323** |
| 15 | .386** | .440** | .333** | .275** | .277** | .303** | .408** | .403** | .180* | .474** | .581** | .532** | .413** | .613** | 1.000 | .544** | .370** | .275** | .278** | .497** |
| 16 | .346** | .422** | .434** | .324** | .288** | .291** | .370** | .491** | .331** | .498** | .590** | .619** | .535** | .519** | .544** | 1.000 | .438** | .324** | .320** | .382** |
| 17 | .210* | .450** | .537** | .535** | .361** | .272** | .401** | .340** | .500** | .463** | .434** | .426** | .524** | .272** | .370** | .438** | 1.000 | .535** | .740** | .583** |
| 18 | .117 | .543** | .418** | 1.000** | .291** | .208* | .387** | .263** | .400** | .378** | .344** | .436** | .365** | .298** | .275** | .324** | .535** | 1.000 | .467** | .422** |
| 19 | .029 | .378** | .513** | .467** | .418** | .317** | .489** | .262** | .461** | .420** | .423** | .433** | .481** | .256** | .278** | .320** | .740** | .467** | 1.000 | .643** |
| 20 | .205* | .386** | .423** | .422** | .612** | .187* | .486** | .274** | .406** | .303** | .478** | .373** | .459** | .323** | .497** | .382** | .583** | .422** | .643** | 1.000 |

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

1 = Fluctuation of prices of materials; 2=Shortages of materials; 3=Changes in material specification and type; 4=Delay in delivery of materials; 5=High cost of labour; 6=shortage of technical personnel; 7=severe overtime; 8=Labour productivity; 9=Labour absenteeism; 10=Shortage of site workers; 11=Financial difficulties of owner; 12=delay payment to supplier /subcontractor; 13= delay in progress payment by owner; 14=Cash flow and financial difficulties faced by contractors; 15=Mode of financing, bonds and payments; 16=Poor financial control on site; 17=Equipment availability and failure; 18=Late delivery of equipments; 19=Insufficient number of equipments; 20=High cost of machinery and its maintenance

Table 5 shows that there is high degree of correlation between cash flow and financial difficulties faced by contractors, and financial difficulties of owner at a significant value of 0.752. Also, equipment availability and failure, and insufficient numbers of equipment are highly correlated at the value of correlation 0.703 as presented graphically in Figure 2.




(a) (b)

Figure 2. Relationship between factors causing cost overrun

## 5. Conclusion

The findings of the study carried out to identify the problems of cost overrun and effect of resource related factors on cost overrun in the state of Johor, Malaysia are summarized as follows:

a) About 85% of the respondents agreed that most construction projects face cost overrun problem.

b) About 11.32% projects face cost overrun above 15%, where the normal range of cost overrun is between 0 and 15%.

c) Fluctuation of prices of materials, cash flow and financial difficulties faced by contractors and shortages of materials were found as most significant factors causing cost overrun.

d) Cash flow and financial difficulties faced by contractor has strong correlation with the financial difficulties of owner.

e) Shortage of site workers, financial difficulties of owner, and cash flow and financial difficulties faced by contractors are significantly inter-correlated between each other.

f) The financial problem faced by the owner and contractor was the most critical issue in construction projects. This often leads to construction delay, and subsequently cost overrun.

g) Financial problems of contractors also influence the procurements of material and arrangement of adequate number of material and equipment. This affects labour productivity. Resolving this issue plays an important role in achieving successful projects.

**Acknowledgements**

The authors would like to thank Universiti Tun Hussein Onn Malaysia for supporting this study. Also, we are thankful to construction practitioners for providing comprehensive and important information, and a lot of cooperation which made data collection easier.

**References**

Abdullah, M. R., Aziz, A. A. A., & Rahman, I. A. (2009). Causes of delay and its effects in large MARA construction project. *International Journal of Integrated Engineering (Issue on Mechanical, Materials and Manufacturing Engineering)*.

Ali, A. S., & Kamaruzzaman, S. N. (2010). Cost performance for building construction projects in Klang valley. *Journal of Building Performance, 1*(1), 110-118.

Ameh, O. J., Soyingbe, A. A., & Odusami, K. T. (2010). Significant factors causing cost overruns in telecommunication projects in Nigeria. *Journal of Construction in Developing Countries, 15*.

Azhar, N., Farooqui, R. U., & Ahmed, S. M. (2008). *Cost Overrun Factors In Construction Industry of Pakistan*. Paper presented at the First International Conference on Construction In Developing Countries (ICCIDC–I) "Advancing and Integrating Construction Education, Research & Practice".

Bryman, A., & Cramer, D. (2002). *Quantative Data Analysis with SPSS Release 10 for Windows* (2nd ed.). Taylor and Francis inc.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.).

Creedy, G. (2005). *Risk factors leading to cost overrun in highway projects.* Paper presented at the Proceeding of Queenland University of Technology Research Week International Conference, Brisbane, Australia.

Daud, Z. M., Ahmad, M. H., & Yusof, F. (2009). *Elementary Statistics*. Preatice Hall, Pearson (M) Sdn Bhd.

Endut, I. R., Akintoye, A., & Kelly, J. (2009). Cost and time overruns of projects in Malaysia. pp. 243-252. Retrieved on August 21, 2009, from http://www.irbnet.de/daten/iconda/CIB10633.pdf

Enshassi, A., Al-Najjar, J., & Kumaraswamy, M. (2009). Delays and cost overruns in the construction projects in the Gaza Strip. *Journal of Financial Management of Property and Construction, 14*(2), 126-151. http://dx.doi.org/10.1108/13664380910977592

Frimpong, Y., Oluwoye, J., & Crawford, L. (2003). Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study. *International Journal of Project Management, 21*, 321-326. http://dx.doi.org/10.1016/S0263-7863(02)00055-8

Just, M. R., & Murphy, J. P. (1994). The effect of resource constraints on project schedules. *Transaction of AACE International, Morgantown*.

Koushki, P. A., Al-Rashid, K., & Kartam, N. (2005). Delays and cost increases in the construction of private residential projects in Kuwait. *Construction Management and Economics, 23*(3), 285-294. http://dx.doi.org/10.1080/0144619042000326710

Latif, Y., Abidin, I., & Trigunarsyah, B. (2008). *Knowledge-based Material Cost Control for Building Construction Project using Expert System Approach.* Paper presented at the CIB International Conference on Building Education and Research, Heritance Kandalama, Sri Lanka.

Le-Hoai, L., Lee, Y. D., & Lee, J. Y. (2008). Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries. *KSCE Journal of Civil Engineering, 12*(6), 367-377.

http://dx.doi.org/10.1007/s12205-008-0367-7

Lock, D. (1993). *Handbook of Engineering Management* (2nd ed.). Oxford: Butterworth- Heinemann.

Long, N. D., Ogunlana, S., Quang, T., & Lam, K. C. (2004). Large construction projects in developing countries: a case study from Vietnam. *International Journal of Project Management, 22*, 553-561. http://dx.doi.org/10.1016/j.ijproman.2004.03.004

Meeampol, S., & Ogunlana, S. O. (2006). Factors affecting cost and time performance on highway construction projects: evidence from Thailand. *Journal of Financial Management of Property and Construction, 11*(1), 3-20. http://dx.doi.org/10.1108/13664380680001076

Memon, A. H., Rahman, I. A., Abdullah, M. R., & Azis, A. A. A. (2010). Factors Affecting Construction Cost in MARA Large Construction Projects: Perspective of Project Management Consultants. *International Journal of Sustainable Construction Engineering and Technology, 1*(2), 41-54.

Moura, H. P., Teixeira, J. C., & Pires, B. (2007). *Dealing With Cost and Time in the Portuguese Construction Industry*. Paper presented at the CIB World Building Congress.

Oladapo, A. A. (2007). A quantitative assessment of the cost and time impact of variation orders on construction projects. *Journal of Engineering, Design and Technology, 5*(1), 35-48. http://dx.doi.org/10.1108/17260530710746597

Omoregie, A., & Radford, D. (2006). *Infrastructure delays and cost escalation: Causes and effects in Nigeria*. Paper presented at the Proceeding of sixth international post graduate research conference.

Padilla, M. E., & Carr, I. R. (1991). Resource strategies for dynamic project management. *Journal of Construction Engineering and Management, 117*(2), 279-293. http://dx.doi.org/10.1061/(ASCE)0733-9364(1991)117:2(279)

Sambasivan, M., & Soon, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management, 25*, 517-526. http://dx.doi.org/10.1016/j.ijproman.2006.11.007

Wong, P. S. P., & Cheung, S. O. (2005). Structural Equation Model of Trust and Partnering Success. *Journal of Management in Engineering, 21*(2), 70-80.

Yang, J. B., & Ou, S. F. (2008). Using structural equation modeling to analyze relationships among key causes of delay in construction. *Canadian Journal of Civil Engineering, 35*, 321-332. http://dx.doi.org/10.1139/L07-101

Zujo, V., Car-Pusic, D., & Brkan-Vejzovic, A. (2010). Contracted price overrun as contracted construction time overrun function. *Technical Gazette, 17*(1), 23-29.

# Call for Manuscripts

*Modern Applied Science (MAS)* is an international, double-blind peer-reviewed, open-access journal, published by the Canadian Center of Science and Education. It publishes original research, applied, and educational articles in all areas of applied science. It provides an academic platform for professionals and researchers to contribute innovative work in the field. The scopes of the journal include, but are not limited to, the following fields: agricultural and biological engineering, applied mathematics and statistics, applied physics and engineering, chemistry and materials sciences, civil engineering and architecture, computer and information sciences, energy, environmental science and engineering, mechanics. The journal is published in both print and online versions. The online version is free access and download.

We are seeking submissions for forthcoming issues. All manuscripts should be written in English. Manuscripts from 3000–8000 words in length are preferred. All manuscripts should be prepared in MS-Word format, and submitted online, or sent to: mas@ccsenet.org

**Paper Selection and Publishing Process**

a) Upon receipt of a submission, the editor sends an e-mail of confirmation to the submission's author within one to three working days. If you fail to receive this confirmation, your submission e-mail may have been missed.

b) Peer review. We use a double-blind system for peer review; both reviewers' and authors' identities remain anonymous. The paper will be reviewed by at least two experts: one editorial staff member and at least one external reviewer. The review process may take two to four weeks.

c) Notification of the result of review by e-mail.

d) If the submission is accepted, the authors revise paper and pay the publication fee.

e) After publication, the corresponding author will receive two hard copies of the journal, free of charge. If you want to keep more copies, please contact the editor before making an order.

f) A PDF version of the journal is available for download on the journal's website, free of charge.

**Requirements and Copyrights**

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the authorities responsible where the work was carried out, and that, if accepted, the article will not be published elsewhere in the same form, in English or in any other language, without the written consent of the publisher. The editors reserve the right to edit or otherwise alter all contributions, but authors will receive proofs for approval before publication.

Copyrights for articles are retained by the authors, with first publication rights granted to the journal. The journal/publisher is not responsible for subsequent uses of the work. It is the author's responsibility to bring an infringement action if so desired by the author.

**More Information**

E-mail: mas@ccsenet.org

Website: www.ccsenet.org/mas

Paper Submission Guide: www.ccsenet.org/submission

Recruitment for Reviewers: www.ccsenet.org/reviewer

The journal is peer-reviewed
The journal is open-access to the full text
The journal is included in:

CABI
Chemical Abstracts database
DOAJ
EBSCOhost
Excellence in Research Australia (ERA)
Google Scholar
Open J-Gate
ProQuest
Scopus
Standard Periodical Directory
Ulrich's
Universe Digital Library

Modern Applied Science
Monthly

Publisher Canadian Center of Science and Education
Address 1120 Finch Avenue West, Suite 701-309, Toronto, ON., M3J 3H7, Canada
Telephone 1-416-642-2606
Fax 1-416-642-2608
E-mail mas@ccsenet.org
Website www.ccsenet.org/mas

ISSN 1913-1844