A Look at the Statistical Evaluation of Hockey Goalies

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Sharing images from this talk is permitted.
Handbook of Statistical Methods and Analyses in Sports,
Edited by Jim Albert, Mark E. Glickman, Tim B. Swartz, Ruud H. Koning
Hockey Chapters in Handbook . . .

- *Poisson/Exponential Models for Scoring in Ice Hockey*
  by Andrew Thomas

- *Hockey Performance via Regularized Logistic Regression*
  by Robert Gramacy, Matt Taddy, Sen Tian

- *Statistical Evaluation of Ice Hockey Goaltending*
  by Michael Schuckers

- *Educated Guesswork - Drafting in the National Hockey League*
  by Peter Tingling

Can be pre-ordered from Amazon
This Talk

- Incomplete Overview (Too much out there)
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- Focus on work in new chapter in *Handbook of Statistical Methods and Analyses in Sports* Editors: Jim Albert, Mark E. Glickman, Tim B. Swartz, Ruud H. Koning
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- My chapter is *Statistical Evaluation of Ice Hockey Goaltending*
- Data from 2009 to 2013. Ugh
Rob Vollman has a book! Have you heard?
This talk - More

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- Rob Vollman has a book! Have you heard?
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- Update on SLU Hockey
- American talk so if I screw up it’s cause I “care too much”
- ... and consequently I might be done early.
Outline

- Traditional Metrics
Outline

- Traditional Metrics
- Save Percentage/Adjusted Save Percentage
Outline

- Traditional Metrics
- Save Percentage/Adjusted Save Percentage
- Rebounds Rates

Focus only on 5v5, Nonempty Net
Traditional Metrics of Goaltending

- Wins
- Goal Against Average (GAA)
- Save Percentage (SVP)
For shot $i$, $z_i$ is vector of attributes including location, shot type, . . .

$n$ total shots with $i = 1, \ldots, n$

Define $\Phi_i$ by

$$\Phi_i = \begin{cases} 
1 & \text{if shot } i \text{ is saved}, \\
0 & \text{if shot } i \text{ is not saved}. 
\end{cases}$$

Denote time on ice for goalie by $T$

Subscript of $j$, to distinguish between goalies $j = 1, \ldots, J$. 
Wins: A goaltender receives a win if he is on the ice when his team scores the game-winning goal.

For 2015-16: Top Wins Goalies

Holtby(48), Quick(40), Jones(37), Bishop(35), Crawford(35)
Wins

Wins is highly correlated with team performance because involves scoring (not under goalies’s control)

For 2015-16: Top Wins Goalies

Holtby(WAS), Quick(LAK), Jones(SJS), Bishop(TBL), Crawford(CHI)

2015-16: Rinne(NSH) won 34/66 with 0.908 SVP, 6th

League mean was 0.915.
Wins in 2009-10

For 2009-10: Marc-André Fleury won 37/65 games 0.905 save proportion, 6th.

Jonathan Quick won 39/71 games with 0.907 save proportion, 8th.

League mean was 0.908.
Goals Against Average (GAA) is the average number of goals that a goalie concedes per 60 minutes.
In our notation

\[
GAA = 60 \left[ n - \sum_{i=1}^{n} \Phi_i \right].
\]  

(2)
In our notation

\begin{align}
\text{GAA} &= 60 \left[ \frac{n - \sum_{i=1}^{n} \Phi_i}{T} \right]. \\
\text{GAA} &= 60 \left[ \frac{n}{T} (1 - SVP) \right].
\end{align}

(2)  

(3)
GAA

In our notation

\[
\text{GAA} = 60 \left[ \frac{n - \sum_{i=1}^{n} \Phi_i}{T} \right].
\] (2)

\[
\text{GAA} = 60 \left[ \frac{n}{T} (1 - \text{SVP}) \right].
\] (3)

\(n\) and \(T\) are not under goalies' direct control and is function of SVP.

I’ll drop subscript \(j\) unless I’m talking about multiple goalies.
Save Percentage

This is the percentage of shots faced that are saved by the goalie
In our notation:

\[ SVP = \frac{1}{n} \sum_{i=1}^{n} \Phi_i. \]

This is our primary traditional metric.

Goalie has ‘control’ over metric in that they face every shot.
Save Percentage

Been changing over time

Figure 1: NHL League Average SVP by Season 1983 to 2015

Source: Hockey-reference.com
Inherently SVP is composed of two parts:

1. Goalie’s ability to stop a shot of type $u$,
2. How often shots of type $u$ are faced,
SVP Notation

\[ SVP_j = \frac{1}{n_j} \sum_{i=1}^{n_j} \Phi_{ij} = \sum_{u=1}^{\mathcal{U}} G_j(u)S_j(u). \]

where

- \( u \) is type of shots
- \( G(u) \) is a probability that a goalie saves a shot with attributes \( z_u \)
- \( S(u) \) is the probability of facing a shot with attributes \( z_u \)
- \( z_u \) is a vector of descriptors for the attributes of a shot
- \( z_u = (x, y, d, \theta, w, \ldots)^T \) where \( u = 1, \ldots, \mathcal{U} \)
SVP Notation

Shot attributes as recorded by NHL RTSS system:

- X location
- Y location
- Shot Type (Backhand, Slap, Snap, Wrist, Tip, Wrap)
- Angle of shot from center ice
- Distance from net
- Rebound or not, Rush or not
Attributes
SVP

Inherently SVP is composed of two parts:

1. Goalies ability to stop a shot of type $u$, $G(u)$
2. How often shots of type $u$ are faced, $S(u)$
### SVP Notation-Simplified

<table>
<thead>
<tr>
<th>Shots Attributes, $z_u$</th>
<th>Goalie A</th>
<th></th>
<th>Goalie B</th>
<th></th>
<th>Goalie C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$G(u)$</td>
<td>$n_u$</td>
<td>$G(u)$</td>
<td>$n_u$</td>
<td>$G(u)$</td>
<td>$n_u$</td>
</tr>
<tr>
<td>Slap Near</td>
<td>0.900</td>
<td>1200</td>
<td>0.880</td>
<td>100</td>
<td>0.880</td>
<td>500</td>
</tr>
<tr>
<td>Slap Far</td>
<td>0.930</td>
<td>200</td>
<td>0.920</td>
<td>700</td>
<td>0.920</td>
<td>500</td>
</tr>
<tr>
<td>Wrist Near</td>
<td>0.920</td>
<td>500</td>
<td>0.900</td>
<td>300</td>
<td>0.900</td>
<td>500</td>
</tr>
<tr>
<td>Wrist Far</td>
<td>0.930</td>
<td>100</td>
<td>0.910</td>
<td>900</td>
<td>0.910</td>
<td>500</td>
</tr>
<tr>
<td>Overall</td>
<td>0.9095</td>
<td>2000</td>
<td>0.9105</td>
<td>2000</td>
<td>0.9025</td>
<td>2000</td>
</tr>
</tbody>
</table>

Here, $U = 4$ and $S(u) = n_u/n$. 
Long discussions in 'hockey analytics' circles about this.

Argument: Differences in shot distributions for different goalies $S_j(u)$'s tend to even out

In our framework this mean that $S_j(u) \rightarrow \bar{S}(u)$ and $n_j$ increases
where $\bar{S}(u)$ is an average across the league.
Data Issues

There are issues with NHL Data (x,y)’s

- Data from NHL’s RTSS feed has some issues
- x,y coordinates often far from ground truth (video analysis) especially in certain rinks (MSG)
- Spatial tracking data is coming (cf. Basketball)
- I hope it is public

See Schuckers and Macdonald (2014) for more on these issues and what to do with/about them . . .
Adjusting X,Y shot coordinates

From Schuckers and Curro (2013)

Take league average CDF for X and Y separately, $F_X(x)$ and $G_Y(y)$

Calculate CDF’s of X and Y for rink R, for shots by away teams A and for shots by away teams at rink R, RA.

For shot $i$ from rink R,

$$x'_i = \text{round}(F_X^{-1}(F_{XR}(x_i) + (F_A(x_i) - F_{RA}(x_i)))) \quad \text{and}$$

$$y'_i = \text{round}(G_Y^{-1}(G_{YR}(y_i) + (G_A(y_i) - G_{RA}(y_i))))$$

Image warping, see e.g. Pishchulin et al (2012) deal with bivariate nature of data (future work?)
Evaluation of Metrics

Predictability/Reliability: Year to year correlation

Consistency: Within year correlation (even and odd)

Validity: Correlation to Winning or goal differential
## Evaluation of SVP

### Table 1: Intraseason correlation of SVP

<table>
<thead>
<tr>
<th>Season</th>
<th>NHL Average SVP</th>
<th>More than 500 shots Correlation</th>
<th>J</th>
<th>More than 750 shots Correlation</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10</td>
<td>0.9198</td>
<td>0.203</td>
<td>48</td>
<td>0.072</td>
<td>33</td>
</tr>
<tr>
<td>2010/11</td>
<td>0.9221</td>
<td>0.282</td>
<td>46</td>
<td>0.385</td>
<td>32</td>
</tr>
<tr>
<td>2011/12</td>
<td>0.9215</td>
<td>0.180</td>
<td>45</td>
<td>0.165</td>
<td>35</td>
</tr>
<tr>
<td>2012/13</td>
<td>0.9203</td>
<td>0.145</td>
<td>24</td>
<td>0.252</td>
<td>9</td>
</tr>
</tbody>
</table>

$J$ is number of goalies
### Table 2: Correlation in year to year SVP

<table>
<thead>
<tr>
<th>Seasons</th>
<th>More than 500 shots Correlation</th>
<th>More than 750 shots Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10 v 2010/11</td>
<td>0.186 34</td>
<td>0.120 22</td>
</tr>
<tr>
<td>2010/11 v 2011/12</td>
<td>0.018 37</td>
<td>-0.038 28</td>
</tr>
<tr>
<td>2011/12 v 2012/13</td>
<td>0.060 20</td>
<td>0.909 8</td>
</tr>
</tbody>
</table>
Rebounds: a digression

What is the impact of rebounds on SVP?

Are rebounds something goalies can control?

Rebound Rate = \frac{\sum_{i=1}^{n} \delta_i}{\sum_{i=1}^{n} \Phi_i}

where \( \delta_i \) is a 1 if shot \( i \) results in a rebound, zero otherwise.

Myrland (2009), Pettapiece (2013)
### Table 3: Intraseason correlation of Rebound Rate for even and odd shots

<table>
<thead>
<tr>
<th>Season</th>
<th>NHL Average Rebound Rate</th>
<th>More than 500 shots faced</th>
<th>More than 750 shots faced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
<td>J</td>
<td>Correlation</td>
</tr>
<tr>
<td>2009/10</td>
<td>0.0823</td>
<td>0.066</td>
<td>46</td>
</tr>
<tr>
<td>2010/11</td>
<td>0.0825</td>
<td>0.329</td>
<td>48</td>
</tr>
<tr>
<td>2011/12</td>
<td>0.0842</td>
<td>0.512</td>
<td>45</td>
</tr>
<tr>
<td>2012/13</td>
<td>0.0838</td>
<td>0.268</td>
<td>24</td>
</tr>
</tbody>
</table>
### Table 4: Correlation between a goalie’s rebound rate and their save proportion

<table>
<thead>
<tr>
<th>Seasons</th>
<th>More than 500 shots Correlation</th>
<th>J</th>
<th>More than 750 shots Correlation</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10</td>
<td>-0.164</td>
<td>48</td>
<td>-0.114</td>
<td>33</td>
</tr>
<tr>
<td>2010/11</td>
<td>-0.440</td>
<td>46</td>
<td>-0.210</td>
<td>32</td>
</tr>
<tr>
<td>2011/12</td>
<td>-0.261</td>
<td>45</td>
<td>-0.252</td>
<td>35</td>
</tr>
<tr>
<td>2012/13</td>
<td>-0.066</td>
<td>24</td>
<td>-0.195</td>
<td>9</td>
</tr>
</tbody>
</table>
Rebounds

Table 5: Correlation between a goalie’s rebound rate in one year and their rebound rate in subsequent years.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>More than 500 shots</th>
<th>More than 750 shots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
<td>J</td>
</tr>
<tr>
<td>2009/10 v 2010/11</td>
<td>-0.086</td>
<td>61</td>
</tr>
<tr>
<td>2010/11 v 2011/12</td>
<td>0.483</td>
<td>37</td>
</tr>
<tr>
<td>2011/12 v 2012/13</td>
<td>-0.261</td>
<td>20</td>
</tr>
</tbody>
</table>
Two ways to adjust SVP

1. Adjust for the goalie
2. Adjust for the shots
Two ways to adjust SVP

1. Adjust for the goalie
2. Adjust for the shots

Each answers different question
Two ways to adjust SVP

1. Adjust for the goalie
2. Adjust for the shots

Each answers different question

1. What would an average goalie do with shots faced by goalie $j$
2. What would goalie $j$ do with shots faced by average goalie

First historically adjusted SVP, second Shot Neutral SVP (A. Ryder)
Adjusted SVP

What does this look like in our notation
Adjusted SVP

What does this look like in our notation

\[ SVP_j = \sum_{u=1}^{\mathcal{U}} G_j(u)S_j(u) \]

\[ aSVP_{\bar{G}_j} = \sum_{u=1}^{\mathcal{U}} \bar{G}(u)S_j(u) \]

\[ aSVP_{\bar{S}_j} = \sum_{u=1}^{\mathcal{U}} G_j(u)\bar{S}(u) \]

(4)

where \( \bar{G} \) represents average goalie and \( \bar{S} \) represents average distribution of shots.
Adjusted SVP

How to get $\overline{G}(u)$ and $\overline{S}(u)$?

For $\overline{G}(u)$, find league SVP at each $u$
   Smoothing makes replace $\overline{G}(u)$ with $\hat{G}(u)$

For $\overline{S}(u)$, find league average distribution of $u$
   Smoothing replace $\overline{S}(u)$ with $\hat{S}(u)$

Many smoothing (regression) attempts
Adjusted SVP

Smoothing Regression based shot probability models (usually logistic)

Logistic regression with x, y, distance, shot type, angle, change in angle
rebound covariates
Adjusted SVP

More smoothing: Schuckers (2011, 2016)
Spatial smoothing by shot type

NB: in images to follow:

- Data from 2009 to 2013
- 5v5 Non-empty net
- By NHL shot type + rebound + ‘rush’ (Johnson, 2014)
- Eliminated shots based upon unusual recording (7 on ice, etc.)
- Kept locations with errors (clearly some artifacts)
- Adjusted for rink
Adjusted SVP

Backhand Shots

Backhand Shot Probability Contours
Adjusted SVP

Slap Shots
Adjusted SVP

Snap Shots

Snap Shot Probability Contours
Adjusted SVP

Tip-In Shots
Adjusted SVP

Wraparound Shots

Wrap-around Shot Probability Contours
Adjusted SVP

Wrist Shots

Wrist Shot Probability Contours
Adjusted SVP

Rebound Shots

Rebound Shot Probability Contours

level
0.5
0.4
0.3
0.2
0.1
0.0
Adjusted SVP

Rush Shots

Rush Shot Probability Contours
Shot Neutral SVP

Updating: Defense Independent Goalie Rating (DIGR), Schuckers (2011)

\[
DIGR_j = \sum_{u=1}^{U} \tilde{G}_j(u) \bar{S}(u)
\]

\[
= \sum_{u=1}^{U} \left[ \alpha(u) G_j(u) + (1 - \alpha(u)) \bar{G}(u) \right] \bar{S}(u)
\]

where \( \alpha(u) = \frac{n_u}{n_u + n^\dagger} \),

\( n_u \) is the number of shots faced by goalie \( j \), \( j = 1, \ldots, J \)
of shottype \( w \) at strength \( s \) and \( n^\dagger \) is a ‘shrinkage’ constant.
### Table 6: Intraseason correlation of DIGR for even and odd shots using $n^\dagger = 1000$

<table>
<thead>
<tr>
<th>Season</th>
<th>More than 500 shots faced</th>
<th>More than 750 shots faced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
<td>J</td>
</tr>
<tr>
<td>2009/10</td>
<td>0.288</td>
<td>48</td>
</tr>
<tr>
<td>2010/11</td>
<td>0.644</td>
<td>45</td>
</tr>
<tr>
<td>2011/12</td>
<td>0.655</td>
<td>45</td>
</tr>
<tr>
<td>2012/13</td>
<td>0.251</td>
<td>24</td>
</tr>
</tbody>
</table>
More DIGRing around

Table 7: Correlation between a goalie’s DIGR in one year and their DIGR in subsequent years.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>More than 500 shots</th>
<th></th>
<th>More than 750 shots</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
<td>J</td>
<td>Correlation</td>
<td>J</td>
</tr>
<tr>
<td>2009/10 v 2010/11</td>
<td>0.237</td>
<td>34</td>
<td>0.393</td>
<td>22</td>
</tr>
<tr>
<td>2010/11 v 2011/12</td>
<td>0.647</td>
<td>37</td>
<td>0.665</td>
<td>28</td>
</tr>
<tr>
<td>2011/12 v 2012/13</td>
<td>-0.174</td>
<td>15</td>
<td>0.677</td>
<td>6</td>
</tr>
</tbody>
</table>
What about the other adjusted save percentage? $aSVP_{Gj}$? Compare this to SVP.

\[
SVP_j = \sum_{u=1}^{U} G_j(u)S_j(u)
\]

\[
aSVP_{\overline{G}j} = \sum_{u=1}^{U} \overline{G}(u)S_j(u)\]

(5)
Goals Saved

Goals gained (or lost) based upon shots faced by goalie \( j \), \( S_j(u) \) relative to league average

\[
= n_j \sum_{u=1}^{\mathcal{U}} \left[ G_j(u) - \bar{G}(u) \right] S_j(u) \tag{6}
\]

Or Goals Saved Above Average Per 60 (Mercadante, 2015)

\[
\frac{60n_j}{T} \sum_{u=1}^{\mathcal{U}} \left[ G_j(u) - \bar{G}(u) \right] S_j(u) \tag{7}
\]
Incomplete list of things I haven’t talked about

- Royal Road, pre shot puck movement (Valiquette)
- Shot Quality Project (Boyle)
- Career Trajectories (Tulsky and others)
- League Projections (Vollman and others)
- Quality Starts (Vollman)
- Pulling the Goalie (Beaudoin & Swartz, Thomas & Ventura)
Future

- Player tracking data
- Better shot attributes (e.g. speed)
- Better defensive positioning (e.g. obstruction)
- Better information for non-NHL data
- Exorcize the Voodoo
Summary

In general, we know

- Goalies are hard to predict
- Adjusting SVP can improve prediction
- Rebounds impact SVP but not super consistent
- Framework for SVP and aSVP
- So many missing covariates/attributes