Identifying Representative Symbology for Low Visibility Operations/Surface Movement Guidance and Control System (LVO/SMGCS) Paper Charts

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The Volpe Center developed a questionnaire to examine the representativeness of symbol shapes and the usefulness of information depicted on Low Visibility Operations/Surface Movement Guidance and Control System (LVO/SMGCS) paper charts. One-hundred forty-four pilots were shown a series of symbol shapes and responded "Yes" or "No" to whether they considered each symbol shape representative of a given information type. Symbol shapes were presented at increasing levels of context. Pilots then rated the usefulness of information depicted on LVO/SMGCS charts. Pilots identified representative symbol shapes for a geographic position marking, instrument landing system (ILS) hold line, runway guard lights (RGL), stop bar, and the combination of RGL *and* a stop bar. The general shape was usually perceived as representative regardless of variations in features such as border or fill. Pilot opinions of usefulness generally reflected findings for symbol shape representativeness.

Low Visibility Operations/Surface Movement Guidance and Control System (LVO/SMGCS) is a set of special procedures and visual aids designed to enable safe airport operations below 1,200 ft runway visual range (RVR). Each airport that operates under LVO/SMGCS conditions must have LVO/SMGCS charts that illustrate these procedures and visual aids (FAA, 2012). It is important that symbols shown on LVO/SMGCS charts are easy to recognize and understand, since pilots rarely operate under LVO/SMGCS conditions. The symbols currently used on LVO/SMGCS charts vary across chart providers and airports. Current FAA guidance on LVO/SMGCS (FAA, 1996; 2012) does not contain recommendations specific to LVO/SMGCS charts and, to date, no research has examined human factors considerations for LVO/SMGCS chart symbology. Thus, the FAA requested that the Volpe Center gather data to help identify best practices for LVO/SMGCS symbology.

The current study had two goals. The first goal was to identify what symbol shapes pilots consider representative of information shown on LVO/SMGCS charts. The study also examined whether pilots needed context to identify representative symbol shapes or whether they could identify the symbol shapes alone. The second goal of this study was to gather pilot opinions on the usefulness of depicting different types of information on LVO/SMGCS charts.

Methodology

This study was conducted using an online questionnaire. The following sections describe the participants and questionnaire tasks.

Participants

A total of 144 air transport pilots participated in the study. Participants were required to have category (CAT) III qualified experience (preferably 5+ years) or have military LVO/SMGCS training. To

thank pilots for participating, the names of all participants were entered into a random drawing to receive one of fifty $50 gift cards to Amazon.com.

Symbol Shape Representativeness Task

The task focused on seven information types, defined in Table 1. Definitions were not provided during the task.

Table 1.
Information Types and Definitions.

Information Type	Definition
Geographic position marking (GPM)	Pavement marking used to verify aircraft position
Clearance bar	Lights at the holding position of a taxiway/taxiway intersection
Instrument landing system (ILS) hold line	Pavement marking indicating a holding position at the boundary of an ILS critical area
Runway guard lights (RGL)	Lights at the runway hold short point position of a taxiway/runway intersection, indicating the presence of an active runway
Stop bar	Lights at the holding position of a taxiway or runway intersection, used to indicate clearance to enter a runway when turned off
Combination of RGL *and* stop bar	Collocated RGL and stop bar
Non-movement area	Pavement marking outlining the boundary of an area not under air traffic control

For each information type, pilots were shown a symbol shape and asked to respond "Yes" or "No" to whether they considered the symbol shape to be representative of a particular information type. A total of 60 symbol shapes were shown: 27 of the symbol shapes were real symbols currently used on LVO/SMGCS charts to depict the information type in question, and 33 of the symbol shapes were "foils" that are not currently used on LVO/SMGCS charts to depict the information type in question. Note that a foil symbol shape could be a fake symbol, designed by the researchers, or a symbol that is used on LVO/SMGCS charts to depict a different information type. Foil symbol shapes were used to determine whether pilots accepted variations in symbol shape features (e.g., line thickness or shading) to represent the same information as long as the shape was consistent (e.g., all squares).

Symbol shapes were presented to pilots alone (i.e., on a white background) as well as at increasing levels of context. Most information types were shown at four levels of context, presented one at a time in increasing order:

1. Symbol shape shown on a white background (no context)
2. Symbol shape shown with a single taxiway
3. Symbol shape shown with adjacent taxiways and runways
4. Multiples of the symbol shape, shown with adjacent taxiways and runways

The chart background used to provide context was based on FAA prototype LVO/SMGCS charts. The chart background changed for each information type, but it was the same for all symbol shapes shown within each information type. An example question is provided in Figure 1 for the GPM information type.

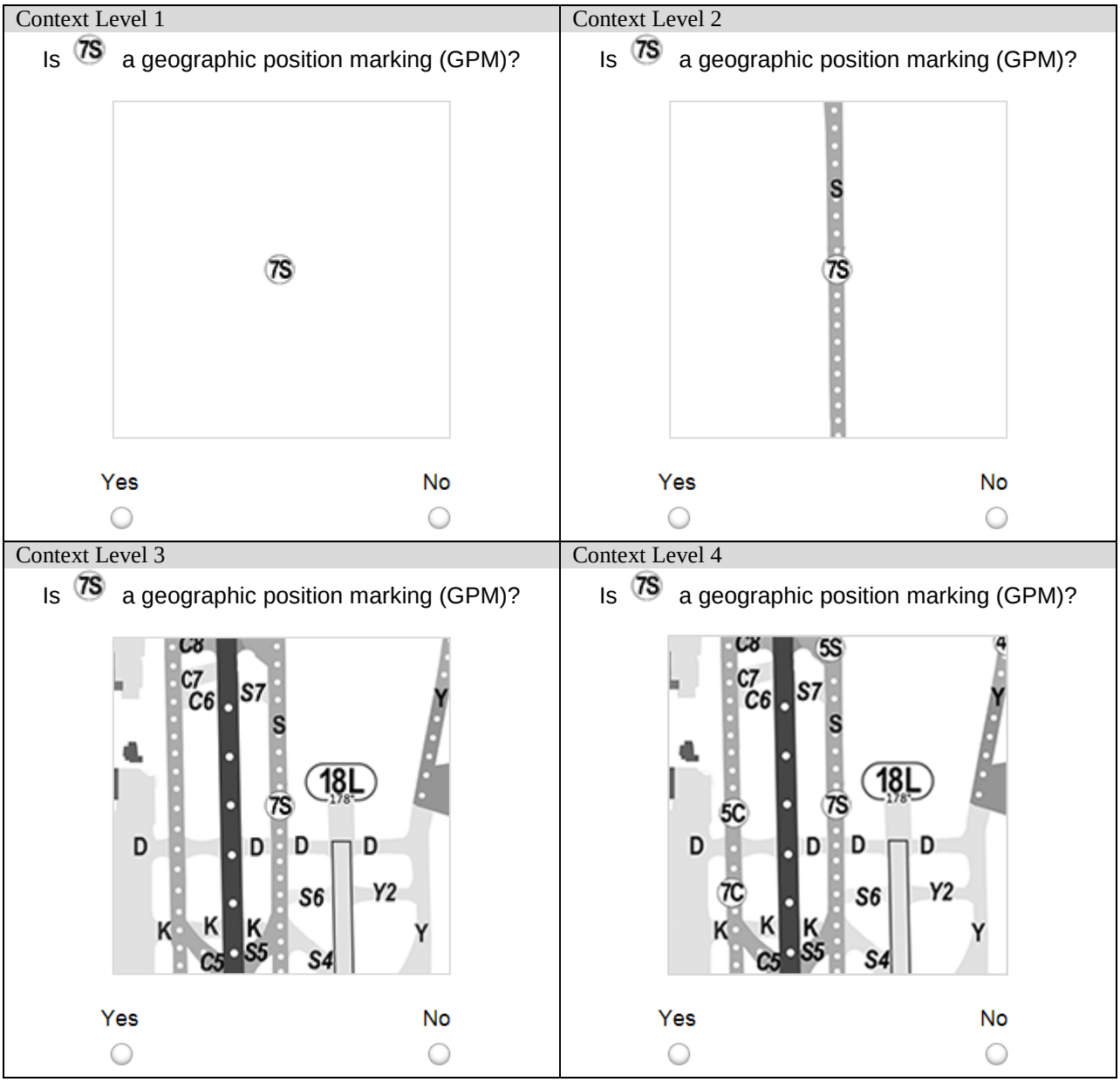

Figure 1. Example of the Symbol Shape Representativeness task for the GPM information type.

Information Type Usefulness Task

In the *Information Type Usefulness* task, pilots were asked to rate the usefulness of nine information types on LVO/SMGCS charts. The nine information types included the seven examined in the *Symbol Shape Representativeness* task (see Table 1) plus two more:

- Approach hold: Pavement marking indicating a holding position at the boundary of a protected approach hold containment area for a runway

- Apron holding point: Pavement marking indicating a holding position at the boundary of an apron

All nine information types were provided in a table with definitions. An excerpt from the table is provided in Figure 2.

Please rate the usefulness of the following information on LVO/SMGCS charts:

	Very Useful	Somewhat Useful	Not Very Useful
Geographic position marking (GPM): Pavement marking used to verify aircraft position	❍	❍	❍

Figure 2. Excerpt from the *Information Type Usefulness* task.

Data Analysis and Results

This section presents the preliminary data and results. More details on this effort and a detailed analysis are documented in Sparko & Chase, in preparation.

Symbol Shape Representativeness

Symbol shape representativeness data were analyzed using chi-square tests comparing the number of "Yes" (representative) responses to the number of "No" (not representative) responses for each symbol shape at each context level. Results were deemed statistically "significant" if there was less than a 5% probability ($p < .05$) that the results occurred by chance. Symbol shapes were considered "representative" if they received significantly more "Yes" responses than "No" responses. Effects of context were observed when the perceived representativeness of a symbol shape changed as context increased. In some cases, pilots needed context to identify a symbol shape as representative.

The representative symbol shapes are shown in Table 2 by information type and need for context. Unless marked as a foil, all of the symbol shapes are used on LVO/SMGCS charts to depict the information type in question. The results show that pilots identified circle shapes as representative of a GPM, regardless of shape outline, fill, text (regular or italic), or context. Ladder shapes were considered to be representative of an ILS hold line, regardless of color or the number rungs. Context was used to identify the foil symbol shape as an ILS hold line; this shape was designed by the researchers to be a variation of the ladder shape with thicker rungs. The fact that pilots needed context to identify this foil symbol shape but not the other ladder shapes suggests that participants associated the the thickness of the rungs with the representativeness of the symbol shape.

Pilots only identified one symbol shape as representative of an RGL, the foil symbol shape , which is used on LVO/SMGCS charts to depict a clearance bar, not an RGL. Context was needed to identify this symbol shape as representative. Pilots identified two *different* symbol shapes as representative of a stop bar. The foil symbol shape , which was designed by the researchers, needed context to be identified as a stop bar. The foil symbol shape , which is used on LVO/SMGCS charts to represent the combination of RGL *and* a stop bar, was identified as representative of a stop bar regardless of context. The same symbol shape was also identified as representative of the combination of RGL *and* a stop bar, suggesting that pilots may not distinguish between these information types on LVO/SMGCS charts. No representative symbol shapes were identified for a clearance bar or a non-movement area. Given that non-movement areas delineate a boundary, this result is not surprising as it may be more relevant to identify whether there is a representative line style used to designate that information type.

Table 2.
Representative Symbol Shapes by Information Type and Need for Context.

Information Type	Context Not Needed	Context Needed
GPM	 (foil)	
ILS hold line		 (foil)
RGL		 (foil)
Stop bar	(foil)	 (foil)
Combination of RGL *and* stop bar		

Information Type Usefulness

Pilot ratings of information type usefulness were analyzed using chi-square tests that compared the number of "very useful," "somewhat useful," and "not very useful" ratings. The results showed that the majority of pilots rated the following information types as "very useful" (all results are statistically significant at $p < .05$):

- ILS hold line (69% of pilots)
- Approach hold (65%)
- RGL (65%)
- Clearance bar (61%)
- Stop bar (60%)
- Combination of RGL *and* stop bar (60%)
- GPM (56%)

Apron holding points received approximately equal numbers of "very useful" (46%) and "somewhat useful" (37%) ratings. Pilots most often rated non-movement areas as "somewhat useful" (49%).

Summary and Conclusion

The results of this study provide input as to what symbol shapes are considered to be representative on LVO/SMGCS charts. For the information types considered here, the findings suggest that pilots may base their perception of representativeness on the overall symbol *shape*. Pilots accepted variations in symbol shape features, such as border, fill, or color, as long as the overall shape was consistent. However, care should be taken when designing symbol shape features to ensure that variations in those features do not alter the symbol shape.

Context helped pilots to identify some "fake" symbol shapes as actual symbols, suggesting that the location of the symbol shape in relation to other chart elements may sometimes be more important than the symbol shape itself. Context may have been helpful in identifying symbol shapes that were unfamiliar or unintuitive. Other symbol shapes, mostly symbols used on LVO/SMGCS charts to depict the information type, were identified regardless of context. Note that the current study did not address information types depicted using variations in linear patterns, which may inherit their meaning based on context.

Pilots identified one symbol shape as representative of both a stop bar and the combination of RGL *and* a stop bar, suggesting that pilots may not distinguish between these information types on LVO/SMGCS charts. Future research might examine the need and operational acceptability of using one symbol shape to represent both a stop bar and the combination of RGL *and* a stop bar on LVO/SMGCS charts.

When asked to give their opinions of information type usefulness, pilots' ratings generally complemented the symbol shape representativeness findings. Pilots identified representative symbol shapes for most of the information types that they considered "very useful" on LVO/SMGCS charts. The one exception was for clearance bars, which were rated "very useful" even though pilots did not identify any representative symbol shapes. Clearance bars, which are usually collocated with GPMs on the airport surface and on charts, may not stand out to pilots on LVO/SMGCS charts, even though pilots believe they are useful. It is also possible that pilots may not know what a clearance bar is by name due to its association with GPMs.

This study is intended to provide data to help the FAA develop best practices for LVO/SMGCS charts. The results provide a general understanding of what symbol shapes may be perceived as representative of certain information types depicted on LVO/SMGCS charts. For some information types, however, additional research may be needed.

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The views expressed herein are those of the authors and do not necessarily reflect the views of the Volpe National Transportation Systems Center or the United States Department of Transportation.

References

Federal Aviation Administration. (1996). *Surface Movement Guidance and Control System* (AC 120-57A). Washington, D.C.

Federal Aviation Administration. (2012). *Procedures for Establishing Airport Low-Visibility Operations and Approval of Low-Visibility Operations/Surface Movement Guidance and Control System Operations* (Order 8000.94). Washington, D.C.

Sparko, A. L., & Chase, S. G. (in preparation). *Low Visibility Operations/Surface Movement Guidance and Control System (LVO/SMGCS) Chart Symbology*. Washington, D.C.: U.S. Department of Transportation.